The Chinese University of Hong Kong

A STUDY OF SELECTED POLLUTION PROBLEMS IN TOLO HARBOUR

by Albert Y.C. Fung

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INTRODUCTION

Pollution can be broadly defined as "any effect of human activity which changes the natural conditions of the environment" (Føyn, 1965); or as "any change in the natural quality of the environment brought about by chemical, physical or biological factors" (Walker, 1971). According to the above two definitions, pollution is not necessarily harmful, for the beneficial addition of fertilizer onto soil - a human effort and a change of natural environment - is also a form of pollution. However, the term 'pollution' is often used in a more restricted sense and only its harmful effects, such as the blockage of a watercourse; alternation in the water quality; adverse influences upon fish production; decrease in the pleasantness of the surroundings; destruction of the health of the community, are stressed. These are seen in the legislation on pollution control of many countries (World Health Organization, 1967).

There are many sources of pollution, and pollutants are usually classified into a number of categories:

1. Human and domestic wastes. These include human excreta, garbage and sewage (Moore, 1954; Mohr, 1959).
2. Industrial products. These include organic wastes (Hood et al, 1960), inorganic wastes (Renn, 1959) and heat from power and industrial plants (Costlow and Bookhout, 1962). The industrial products sometimes contain toxic materials such as heavy metals (Brown and Ahsanullah, 1971).

3. Toxic chemicals. The best known example of such chemicals is DDT. These substances are highly toxic at very low concentrations (Cottam, 1959).
4. Oil from accidental loss or operational discharge (Dixon et al, 1972).
5. Radioactive wastes (Straub, 1959).

In "Waste Management and Control" (National Academy of Science and National Research Council, 1966), eight pollutants are listed. These can be reclassified into the above five categories.

Most of the wastes of human and industrial activities eventually end up in the marine environment. Typical routes are from sewers, rivers, streams, and ships and by the action of wind. The ocean is a well-balanced system in which each part of the system has a specific capacity to receive wastes without undesirable effects. This capacity depends upon the distribution of the resources, the physical processes of advection and diffusion, and the geological, biological and chemical processes of removal (National Academy of Sciences and National Academy of Engineering, 1970). However, this capacity is often exceeded, especially when the water mass is a localized or enclosed area where the circulation is slow. The result is a disturbance of the biological steady state of the sea water or the sea bottom which receives the wastes. Harmful effects of the wastes are shown. Jeffries (1962) studied the polluted Raritan Bay on the eastern U.S. coast. He pointed out that the bay once had supported oysters and diverse fish stocks. However, with the surge of urban growth and industrilization, pollution had brought the demise of the oyster industry and greatly reduced the abundance of fishes. Pollutants of rich nutrient supplies from domestic sources, aggravated by a sluggish circulation, altered the natural nutrient cycles of phosphate and nitrate salts. The surface inorganic phosphate-phosphorus concentrations recorded in Raritan Bay were 1.78 to 4.29 µg.a./L. The nitrate-nitrogen concentrations were 6.7 to 34.7 µg.a./L. Pollutants also reduced the dissolved oxygen concentration. A sharp dissolved oxygen gradient was found in August, 1957 to extend from the head of the bay (3.71 ppm) to the centre of the bay (9.90 ppm). Bartsch et al (1967) undertook oceanographic studies of Puget Sound on the western coast of U.S.A. to evaluate the pollution problems. They found that the sulphite waste liquor was the cause of the turbidity of the water and the decrease of dissolved oxygen and pH.

Water is a substance which has a great specific heat. Its temperature is affected by the atmosphere, especially at the surface, but the change is gradual and is within a small range. The average daily surface temperature range of the oceans is approximately 0.2° to 0.3° C. (Sverdrup et al, 1942). A water mass maintains a fairly uniform constant temperature. Temperature mixing with other water masses is slow unless the water mass receives a heavy environmental impact. One such impact reported upon in recent years is the thermal addition caused by the cooling water from electric power plants or heated wastes from industrial factories (Kinne, 1970). Thus, measurement of temperature helps not only to characterize a water mass but also to detect if there is any pollution by heat.

To a layman's eye, water is clean or dirty depending upon whether the water is clear or turbid. In fact, turbidity and light penetration are factors affecting water quality (Bartsch, 1959). Light penetration measured by a Secchi disc is the simplest way of comparing the relative amount of suspended particles of industrial and domestic wastes in the water. There is no absolute standard for the measurement of light penetration using a Secchi disc, but usually less than 2 metres (or six feet) is regarded as turbid (Bartsch et al, 1967).

An equally important factor characterising a water mass is salinity. Salinity has long been used as a tracer for the labelling of different water masses (Mangelsdorf, 1967). The normal surface water salinity at 20^{o} latitude is 35.3 $^{o}/oo$ (Sverdrup et al, 1942). Human activities occassionally affect salinity. One example is the pumping of large volumes of fresh water into an estuary (Cronin, 1967). Salinity has been demonstrated to be able to indicate relative degrees of pollution. A high salinity reading is always recorded at the mouth of any harbour (Crippen and Reish, 1969).

Sea water is a very good buffer. The pH found in the sea is between about 7.5 and 8.4. Near the surface, where the water is in equilibrium with the carbon dioxide in the air and the buffering capacity is the greatest, the pH is within a very narrow range of 8.1-8.3 (Sverdrup et at, 1942). This buffering capacity is inhibited, however, if the water is mixed with a large quantity of pollutants of high acidity or basicity (Nitta, 1961). pH is easily determined and is a useful indicator in determining if the water is polluted.

The wastes, particularly the organic components, introduced into the sea are decomposed with the help of micro-organisms, oxygen being consumed in the process. Thus a determination of the amount of oxygen present in a water sample i.e. the dissolved oxygen or the amount of oxygen that can be consumed by the oxidizable materials present can be a primary indicator of water quality (Thomann et al, 1968). The most frequently used test of the latter category is the BOD_5 test (5-day 'Biochemical Oxygen Demand' test). BOD_5 is the oxygen in ppm required during stabilization of the decomposable organic matter by aerobic bacterial action. Every country sets its own standard. The highest permissible values vary from 2 ppm in the Union of the Soviet Socialists Republic to 100 ppm in Belgium, depending on how the water is used (World Health Organization, 1967). High BOD_5 is always related to high organic content (Waldichuk, 1959).

In recent years serious pollution problems have always been created by sewage outfalls. The sewage can often be detected by a high concentration of phosphate and nitrate salts (Becacos-Kontos and Dugdale, 1971). In nature there are cycles of nitrogen and phosphorus (Sverdrup et al, 1942). The availability in 'average' sea water of phosphorus is 2.3 mg.a./m^3 (1 mg.a./m^3 = 1 μg.a./L.) and that of nitrigen is 34.5 mg.a./m^3 (Collier, 1970). According to some authors, the concentration of phosphate-phosphorus in marine water is less 1-60 μg./L. (1 μg./L. = 0.0105 μg.a./L.) that of nitrate-nitrogen 1-600 μg./L. (1 μg./L. = 0.016 μg.a./L.) (Harvey, 1966). Unusually high concentrations of nitrate and phosphate salts are found in places which are polluted e.g. Raritan Bay which was shown to possess a maximum concentration of phosphate and nitrate at 4.29 µg.a./L. and 34.7 µg.a./L. respectively (Jeffries, 1962).

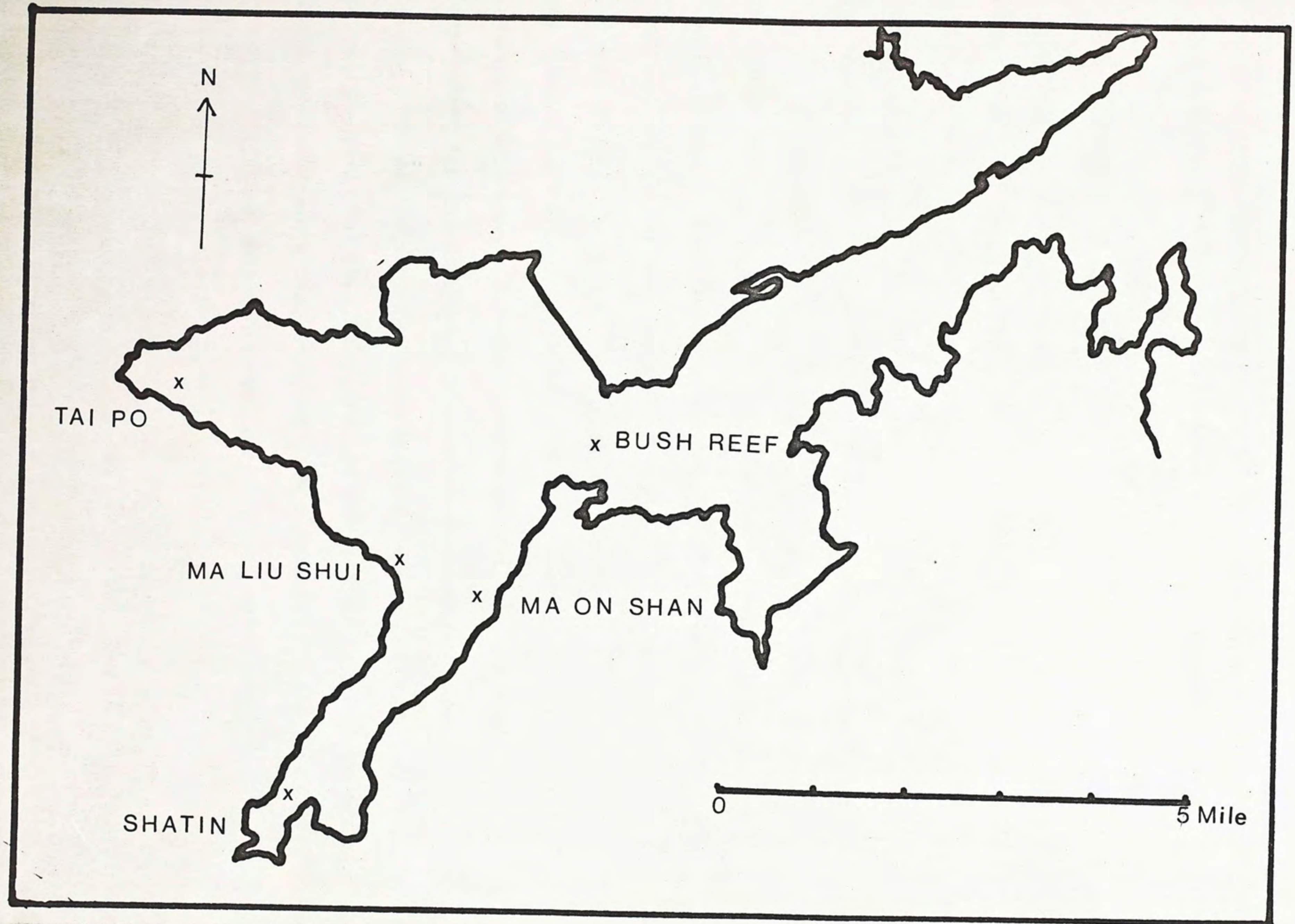
Coliform bacteria include a number of genera of bacteria such as *Escherichia*, *Aerobacter* and *Klebsiella*, which are Gram-negative, non-spore forming bacilli capable of fermenting lactose with the production of acids and gases within 24 hours at 37°C., and able to grow aerobically on an agar medium containing bile salt. Coliform bacteria are human enteric inhabitants. They normally cannot survive in marine environments (Harris, 1958; Greenberg, 1956). Their T-90 ranges from 2 to 20 hours, the average range being 3 to 8 hours (Zobell, 1959). T-90 is the time required for a 90% reduction in the number of coliform bacteria detected by Standard Methods (American Public Health Association, 1955). The bactericidal action of sea water, dilution, and predation by zooplankton may account for the decrease in coliform bacteria (Ketchum *et al*, 1952). Thus any population of coliform bacteria found in the sea must be due to a continuous imput of sewage containing faecal matter. Testing for coliform bacteria gives an effective estimate of the degree of pollution (Rittenberg, 1956). Coliform bacteria are not evenly distributed in the sea (Ketchum, 1955). Their density in water is represented statistically as Most Probable Numbers (Hoskins, 1934; DallaValle, 1941). In many countries such as New Zealand and many states of U.S.A., a MPN of 1000/100 ml. is regarded as the highest permissible limit for bathing and 50/100 ml. as the limit for edible clam collection (Garber, 1956; World Health Organization, 1967).

GNP/Area Ratio can be used as a measure of the potential pollution of a country because the gross national product (GNP) is related to the flow of materials through a society. The materials are resulted from its various domestic, industrial and agricultural activities (Goldberg and Bertine, 1971). The leaks of such materials to the natural environment constitute pollution. Of 84 other large and small countries and areas in the world, Hong Kong is highest with a GNP/Area ratio of U.S. $\$2.5 \times 10^9$/year/$Km^2$ (Montagu, 1971), which means that Hong Kong is potentially most likely to be affected by pollution problems because of its greatly developed economy and limited land.

Pollution problems are important and possess a great significance for the Hong Kong community. Because of this, a study has been undertaken into the pollution of Hong Kong. Owing to the location of the Marine Science Laboratory, work has been concentrated on Tolo Harbour and its towns, Shatin and Tai Po, which have their sewage and wastes improperly treated and carelessly discharged into the harbour. My aim is to present a comparative ecological study of the harbour to see whether or not, and to what extent, the harbour is polluted.

Tolo Harbour is a large body of water with an approximate area of 20 square miles. It is situated in the north-east quarter of the New Territories, Hong Kong. It is almost enclosed by land, save for a narrow channel extending to the open sea (Figure 1). It is shallow, most of the inshore reaches being less than 10 m. deep. In summer, the harbour receives a considerable amount of fresh water from rivers and streams. These rivers and streams are typically dry in the winter months. The

Figure 1 : Map of Tolo Harbour, showing the town sites and the five sampling stations



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harbour is bordered by two major towns, Shatin to the south, and Tai Po to the north. A number of smaller towns e.g. Ma Liu Shui and Ma On Shan also line the harbour. These towns are affecting the ecology of the harbour.

Very little is known about the harbour. A limited number of papers have been published. Hwang and Kwan (1966) used local specimens of horseshoe-crabs for physiological studies. Tschang (1966) worked on the marine geology. These provide some information but bear no direct relevance. Dr. L.B. Trott, the initiator and the present Director of the Marine Science Laboratory, C.U.H.K., has been undertaking ecological studies in the harbour since 1967, and has several papers in press (Trott, 1972 a,b, and c, In press). Except for these, this study was carried out without any background of published materials.

The pollution problems posed by a body of water like Tolo Harbour are varied and complex. A detailed study of all aspects would require tremendous work outside the capacity of a single investigator. Thus only selected problems were examined. The basic water quality parameters used by Jeffries (1962) and Bartsch _et al_ (1967) for oceanographic studies of polluted bays, such as temperature, light penetration, salinity, pH, dissolved oxygen, phosphate-phosphorus and nitrate-nitrogen were utilised. In addition, the occurence of coliform bacteria and biochemical oxygen demand, which have become common 'tools' for pollution detection and measurement (Odum, 1959), were included.

MATERIALS AND METHODS

Five stations in Tolo Harbour were visited on a weekly basis from March, 1971 to February, 1972. The stations were : (Figure 1)

1. Ma Liu Shui : the campus site of the Chinese University of Hong Kong. Population less than 2,000.
2. Ma On Shan : opposite to Ma Liu Shui, the site of an iron mine. Population approximately 3,000.
3. Shatin : a 'satellite' town on the south western end of Tolo Harbour. There is a dyeing factory one mile from the town proper. Population 29,478 (1971 Census data, from Hong Kong Statistics Department).
4. Tai Po : Another 'satellite' town on the north of the harbour, with a large fishing village and thousands of boat inhabitants. Population 44,040 (1971 Census data, from Hong Kong Statistics Department).
5. Bush Reef : a small rocky reef almost at the centre of the harbour. Though frequented by fishing boats, there is no population and the environment is presumably not interferred with by human activities to any great extent.

(These five stations will be abbreviated as MLS, MOS, S, TP, and BR in the figures.)

On each trip, water and sediment samples from a specific site (determined with reference to hills etc.) at each stations were taken for analysis. The time which elapsed between the first and last stations visited was within a two hour span so that comparison of ecological characteristics could be made. These were performed as follows:

1. Temperature : water temperature was measured with an alcohol-in-glass thermometer or a mercury-in-glass thermometer.
2. Turbidity : vertical turbidity of the sea water was measured by the depth to which a standard Secchi Disc could not be seen from the surface.
3. Salinity : salinity was calculated from the chlorinity, determined by the Knudsen method of silver nitrate titration (Chan, 1965; American Public Health Association, 1970), and since April, 1971, by an A-O Refractometer (Martin, 1968).
4. Dissolved oxygen : this was determined by the Pomeroy-Kirschman modification of the Winkler's method (Allan Hancock Foundation, 1958; American Public Health Association, 1970). Occasionally dissolved oxygen was determined by means of a Beckman D.O. analyser.
5. pH : Field and laboratory TOA pH meters were used.
6. Phosphate: the water samples were collected in sterilized dark polythylene containers. A few drops of chloroform were added to prevent bacterial action. The water samples were brought back to the laboratory, filtered, and the filtered samples analysed immediately using the molybdenium method (Armstrong, 1965). The blue color was read with a Coleman Model 14 spectrophotometer, using a 4-cm. oblong curvette and a PC-5 filter at 680 mμ.

7. Nitrate : the water samples collected and treated for the analysis of phosphate were also used for the determination of nitrate using the reduced strychnidine method (Allan Hancock Foundation, 1958). From September, 1971, the zinc reduction and Griess reagent method of Chan (1965) was also employed. The pink color developed in the dark was read with a Coleman Model 14 spectrophotometer using a 1.9 cm. round cuvette and at 543 mμ.

For both phosphate andnnitrate determinations, standards were made and compared with the experimental results.

8. Coliform bacteria : water samples used for the estimation of coliform bacteria were collected by a modified Zobell bacterial sampler (Zobell, 1941; Sieburth, 1963), and for the sediments, a bacterial bottom sampler (Emery, 1958) was used.

Presumptive tests with lactose broth, confirmed tests using Eosin Methylene Blue Agar, and completed tests with Gram's stain were carried out according to the Standard Methods (American Public Health Association, 1955; Ministry of Health and Ministry of Housing and Local Government, 1957). Inoculation was performed under 'on site' conditions on our research vessel. The water samples were inoculated directly, after dilution with phosphate buffer if necessary, into the media. Incubation followed one or two hours later in the laboratory (Orlob, 1956). By checking the tables in the Standard Methods, the Most Probable Numbers (MPN) of the coliform bacteria present in the water samples were found (Hoskins, 1934; DallaValle, 1941).

For the sediments, the whole sample of sediment contained in the bacterial sampling tube of fixed surface area was transferred to sterile water blank of the appropriate volume to give an initial dilution of 2.5 $cm.^2$ of surface area per 100 ml. of suspension. The sample was shaken, further diluted if necessary, and inoculated following a similar procedure used in the examination of water and adopted by Rittenberg et al (1958). The results obtained were reported as $MPN/cm.^2$ of sediment surface.

A number of preliminary surveys on the horizontal distribution of coliform bacteria in the water in Shatin Hoi and at Tai Po were carried out in February and March, 1971. On 4th February, 1971, seven water samples were collected in the Shing Mun River and in Shatin Hoi. The first three sampling sites were approximately 1000 metres apart from each other and the last four were approximately 500 metres apart from each other. On 23rd February, 1971, fifteen water samples were collected in Shatin Hoi at low tide. There were three transect lines. On each line, each sampling stations was approximately 300 metres apart from the next. A similar survey was carried out on 9th March, 1971 in Shatin Hoi when the tide was high. On 26th February, 1971, 13 water samples were collected at Tai Po at low tide. There were four transect lines. On each line each sampling station was approximately 500 metres apart. A similar survey was carried out on 16th March, 1971 at Tai Po when the tide was high.

The water samples were analysed for coliform bacterial counts.

16 tests were undertaken on the tissues of clams collected at Shatin for the presence of coliform bacteria by the 'Percentage Clean' method (Collins, 1967). 10 clams were used for each test. 2 tests were carried out on Katelysia rumularis (Linné). 2 tests were carried out on Tapes sp. The remaining 12 tests were carried out on Anomalodiscus squamosus (Linné).

9. Biochemical Oxygen Demand : 250 ml. dark BOD bottles were sterilized by dry heat at 180°C. for an hour before being taking into the field. Water was collected and dissolved oxygen was determined at the time of sampling. After incubation at 20°C. for five days, the dissolved oxygen was again determined and the BOD_5 was found. Other detailed procedures follow these given in Standard Methods (American Public Health Association, 1955).

In addition to the weekly samples, on several occasions, other areas in the harbour were sampled. Dissolved oxygen, BOD_5, and the number of coliform bacteria in the sediments were determined for 29-33 areas covering nearly the whole of Tolo Harbour.

RESULTS

The results of the one year study from March, 1971 to February, 1972 are summarized below:

1. Temperature:

There were fluctuations in the surface water temperature of the various stations during the year (Table I and Figure 2), with a maximum of approximately 30°C. in July and a minimum of approximately 16°C. in January. There were differences amongst the stations, but the differences were not great and usually within one degree centigrade. (The annual means are shown in Table XIV.)

2. Turbidity:

The vertical turbidity of the sea water at various stations measured by the visual disappearance of Secchi disc are shown in Table II and plotted in Figure 3. The differences in turbidity amongst the stations were well marked, with the least turbidity at Bush Reef, more turbid waters at Ma Liu Shui and Ma On Shan, and most turbid waters at Tai Po and Shatin. (The annual means are shown in Table XIV)

3. Salinity:

Except for Shatin, the other four stations have more or less the same pattern of salinity variations. The lowest salinity (26°/oo) occured in July and the highest (30°/oo) in November and December. (Table III and Figure 4.)

Salinity changes at Shatin roughly followed the same pattern.

Table I : Surface water temperature of Tolo Harbour, 1971-72 (^oC)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	18.4±1.2 (15.2-20.7)	18.4±1.2 (15.3-20.7)	19.1±0.8 (17.4-20.3)	19.3±0.6 (18.0-20.6)	20.5±0.0 (20.5-20.5)
Apr.	23.9±0.3 (23.2-24.3)	23.7±0.1 (23.0-24.0)	24.6±0.5 (23.8-25.5)	24.2±0.5 (23.2-25.4)	23.7±0.6 (22.2-24.8)
May	25.2±0.2 (23.8-28.5)	25.4±2.3 (23.3-29.5)	25.5±1.1 (23.6-29.5)	25.6±0.1 (23.7-29.5)	25.2±0.9 (23.5-28.5)
Jun.	29.2±0.7 (27.5-30.4)	29.1±0.4 (28.0-29.7)	29.3±0.9 (28.0-30.6)	29.7±0.9 (27.0-31.5)	28.8±0.7 (27.0-29.8)
Jul.	30.5±0.4 (29.5-31.0)	29.5±0.7 (27.4-30.7)	30.3±0.7 (29.3-32.3)	30.1±0.2 (29.5-30.5)	29.9±0.5 (29.0-31.5)
Aug.	28.3±0.8 (26.0-30.8)	27.4±0.7 (26.1-29.5)	27.6±0.4 (26.5-28.6)	28.9±0.7 (26.4-30.8)	28.1±0.8 (26.7-30.5)
Sep.	28.6±0.5 (27.8-30.2)	28.5±0.4 (27.5-29.5)	29.1±0.4 (27.6-30.5)	29.4±0.6 (27.7-30.7)	28.8±0.4 (27.8-29.9)
Oct.	25.3±0.4 (22.6-27.5)	25.4±0.7 (23.9-27.3)	24.4±0.6 (21.8-26.8)	25.7±0.6 (24.0-27.2)	25.7±1.2 (24.3-27.5)
Nov.	22.3±1.0 (19.8-24.6)	22.3±1.0 (20.2-25.0)	21.8±1.9 (18.4-25.2)	22.7±1.1 (20.4-25.3)	22.6±1.0 (20.3-24.7)
Dec.	18.3±0.5 (17.3-19.4)	18.4±0.7 (16.7-19.5)	17.9±0.6 (16.8-19.2)	19.2±0.6 (18.6-19.8)	19.2±0.5 (17.8-21.0)
Jan.	17.0±0.7 (15.8-18.7)	16.5±0.5 (15.2-17.6)	16.0±1.2 (12.9-18.0)	17.2±0.6 (15.6-18.0)	17.5±0.5 (16.3-18.7)
Feb.	16.9±1.0 (14.0-18.7)	17.1±1.3 (13.6-19.0)	17.1±1.9 (11.6-20.1)	17.2±1.1 (13.5-19.3)	16.8±0.6 (15.0-17.8)

Figure 2 : Surface water temperature of Tolo Harbour, 1971-72

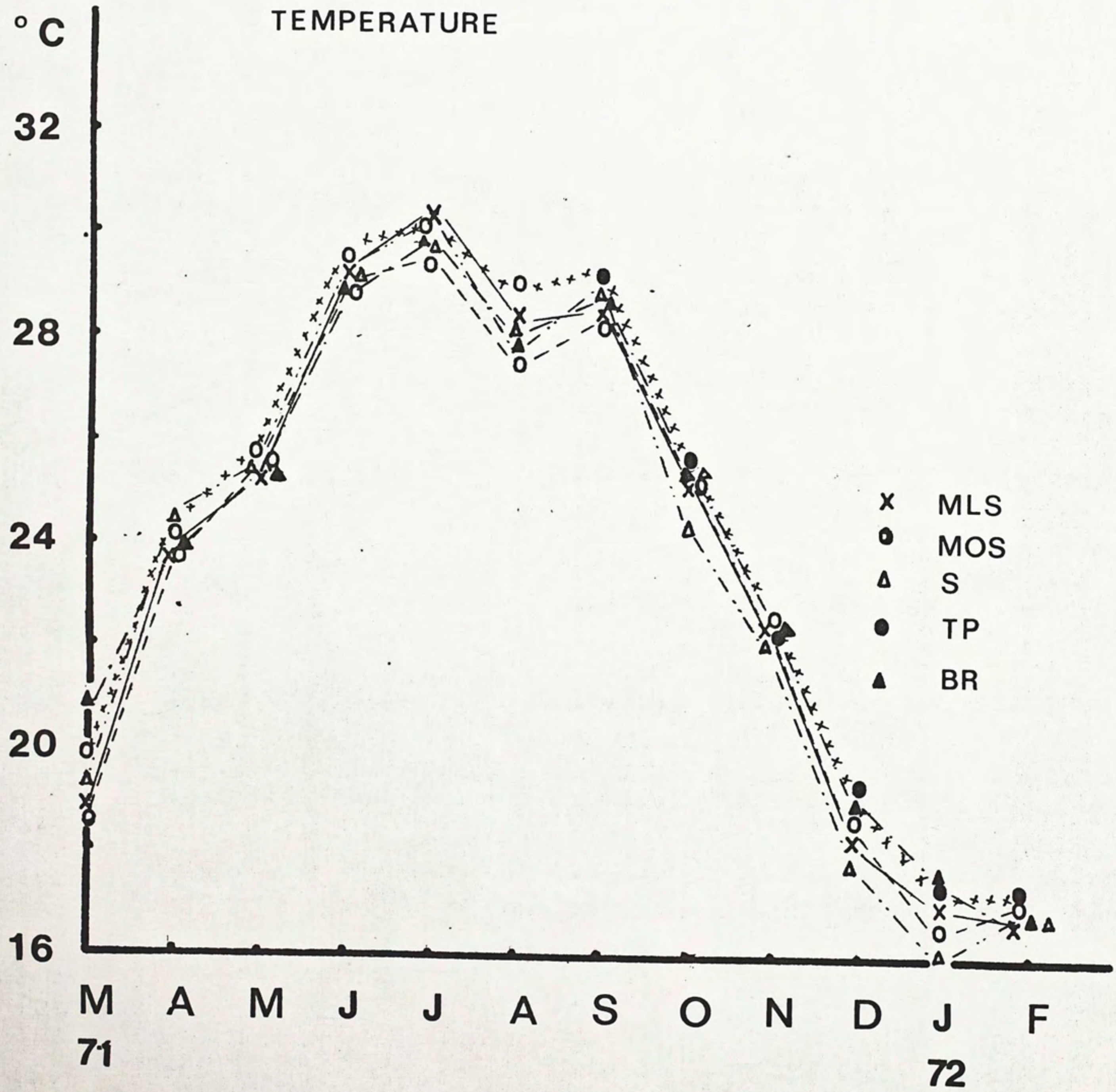


Table II : Water Turbidity of Tolo Harbour, 1971-72, expressed as Secchi disc visibility (feet)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	8.2±0.5 (7.0-9.0)	10.2±1.4 (7.0-14.0)	6.5±0.8 (5.0-9.0)	6.0±0.1 (5.0-7.0)	18.0±2.0 (16.0-20.0)
Apr.	10.0±1.2 (8.0-12.0)	8.5±2.8 (5.0-12.0)	5.7±0.7 (4.0-7.0)	5.5±0.6 (4.0-7.0)	15.0±0.6 (14.0-16.0)
May	8.6±0.8 (6.0-10.0)	9.0±0.3 (8.0-10.0)	5.3±0.7 (2.5-7.0)	6.2±0.1 (5.0-7.0)	14.0±0.6 (12.0-15.0)
Jun.	6.0±0.4 (5.0-7.0)	6.5±0.3 (6.0-7.0)	4.7±0.6 (3.0-6.0)	4.6±0.6 (3.0-6.0)	17.5±1.5 (15.0-22.0)
Jul.	7.0±0.9 (6.0-9.0)	7.5±0.9 (5.0-10.0)	4.8±0.7 (3.0-6.0)	4.2±0.7 (3.0-6.0)	17.0±1.5 (14.0-20.0)
Aug.	8.2±0.4 (7.0-9.0)	6.4±0.9 (3.0-8.0)	6.0±0.3 (5.0-7.0)	6.2±0.1 (5.0-8.0)	16.4±0.9 (14.0-19.0)
Sep.	7.2±1.3 (5.0-11.0)	6.7±0.5 (6.0-8.0)	5.7±0.2 (5.0-6.0)	6.9±0.7 (5.5-9.0)	19.5±0.4 (12.0-31.0)
Oct.	8.6±0.2 (5.0-14.0)	7.0±0.4 (6.0-8.0)	4.6±0.2 (4.0-5.0)	5.0±0.6 (4.0-7.0)	14.6±1.9 (9.0-22.0)
Nov.	8.7±1.0 (7.0-11.0)	6.9±1.5 (5.0-11.5)	5.7±0.4 (5.0-7.0)	6.7±0.6 (5.0-8.0)	17.0±1.0 (16.0-20.0)
Dec.	11.2±0.6 (10.0-14.0)	9.0±0.6 (7.5-11.0)	5.3±0.3 (4.5-6.0)	6.8±0.5 (5.5-8.0)	15.9±2.2 (7.0-21.0)
Jan.	16.2±1.5 (13.0-20.0)	8.7±1.1 (4.5-13.0)	4.7±0.4 (3.5-5.5)	12.5±0.4 (6.0-25.0)	20.0±2.3 (15.0-25.0)
Feb.	13.2±0.8 (12.0-15.0)	9.2±0.9 (8.0-12.0)	5.0±0.4 (4.5-6.0)	8.5±1.4 (5.0-12.0)	18.2±1.0 (16.0-20.0)

Figure 3 : Water turbidity of Tolo Harbour, 1971-72

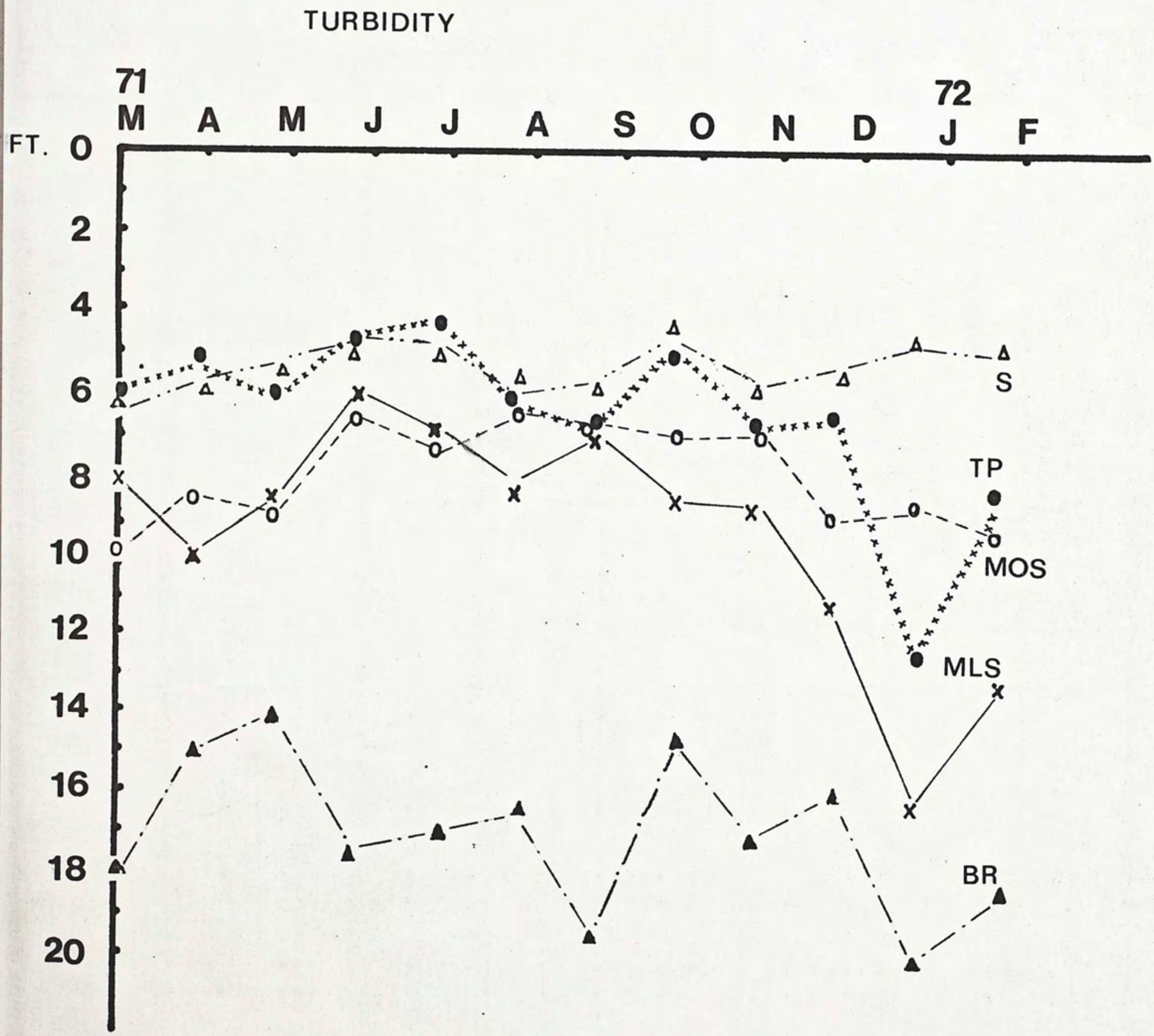
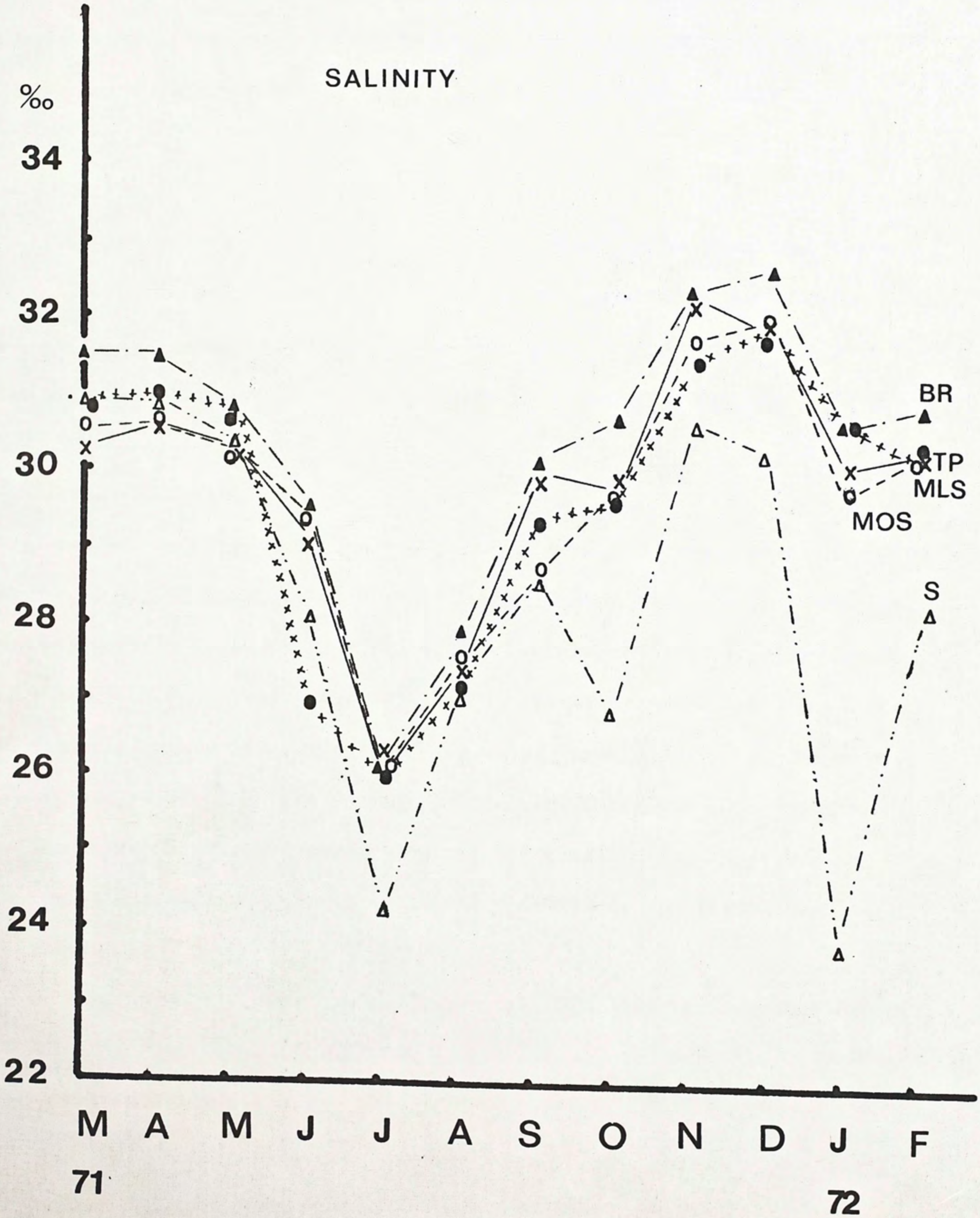


Table III : Surface water salinity of Tolo Harbour, 1971-72 ($^{o}/oo$)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	30.3±0.2 (30.0-30.5)	30.5±0.0 (30.5-30.5)	30.9±0.1 (30.5-31.0)	30.9±0.4 (30.5-31.0)	31.5±0.6 (31.0-32.0)
Apr.	30.6±0.3 (30.5-31.0)	30.6±0.1 (30.5-31.0)	30.9±0.1 (30.5-31.0)	31.0±0.0 (31.0-31.0)	31.5±0.0 (31.5-31.5)
May	30.3±0.5 (28.5-31.5)	30.3±0.4 (28.5-31.5)	30.4±0.5 (29.8-31.0)	30.8±0.2 (30.0-31.0)	30.9±0.6 (28.5-32.0)
Jun.	29.1±0.5 (27.5-30.0)	29.4±0.5 (28.0-30.5)	28.1±0.9 (26.2-30.0)	27.0±1.6 (24.0-28.0)	29.6±0.5 (28.0-31.0)
Jul.	26.1±0.6 (24.5-27.5)	26.0±0.5 (24.5-26.5)	24.2±1.4 (20.1-26.7)	26.0±0.5 (24.5-27.0)	26.2±0.2 (26.0-27.0)
Aug.	27.4±0.5 (17.5-30.5)	27.5±0.8 (20.5-30.5)	27.2±1.0 (24.0-29.5)	27.2±0.3 (18.5-30.5)	27.8±2.4 (18.5-31.0)
Sep.	30.0±0.8 (28.5-32.0)	28.7±0.6 (27.8-30.5)	28.6±0.5 (28.0-30.0)	29.4±0.1 (28.0-30.5)	30.2±0.7 (28.5-32.0)
Oct.	29.8±0.7 (28.0-31.5)	29.8±0.8 (28.0-31.5)	26.9±0.7 (25.0-28.5)	29.6±0.6 (27.5-31.0)	30.7±0.5 (29.5-32.0)
Nov.	32.3±0.2 (32.0-32.5)	31.8±0.5 (30.5-32.5)	30.7±0.6 (29.5-32.0)	31.5±0.3 (31.0-32.0)	32.4±0.2 (32.0-33.0)
Dec.	31.9±0.5 (30.1-32.5)	32.0±0.5 (30.0-33.0)	30.3±0.9 (27.5-32.0)	31.9±0.2 (31.0-32.5)	32.7±0.5 (31.0-34.0)
Jan.	30.1±0.7 (28.5-32.0)	29.8±0.3 (29.0-30.5)	23.9±2.9 (18.0-29.5)	30.7±0.1 (30.5-31.0)	30.7±0.3 (30.0-31.5)
Feb.	30.3±0.3 (30.2-31.0)	30.3±0.2 (29.8-31.0)	28.2±0.3 (27.5-29.0)	30.2±0.2 (29.8-30.5)	30.9±0.6 (30.2-31.5)

Figure 4 : Surface water salinity of Tolo Harbour, 1971-72



However, as shown in Figure 4, the water was usually less saline and the fluctuations were far greater than for all the others, showing a comparatively greater influence of fresh water. The annual salinity mean at Shatin was more than one part per thousand lower than at other stations. (Table XIV).

4. pH :

With reference to Table IV and Figure 5, it can be seen that there were fluctuations in the monthly pH of the sea water from the various stations. The water at Shatin was often lower in pH (less basic) than the water at other stations and extremes of pH were more common. (Table XIV).

5. Dissolved oxygen :

Table V and Figure 6 show the monthly dissolved oxygen content of the surface water in mg./L. The dissolved oxygen data are also presented as percentage of saturation in Table VI and Figure 7. These are the ratios of the actual dissolved oxygen divided by the expected saturated values at the temperature and salinity of the water samples, with reference to the Oceanographical Tables (Zubov, 1957). The dissolved oxygen content is the lowest in the hot months for all the stations, and is the highest in the cold months; supersaturation was recorded for most stations in January.

There were some vary low readings at Ma Liu Shui in September (36.0%), at Tai Po in September (36.0%), at Shatin in July and September (37.6% and 33.0% respectively).

Table IV : Surface water pH of Tolo Harbour, 1971-72

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	8.15±0.07 (8.00-8.30)	8.15+0.19 (7.90-8.30)	8.05±0.07 (7.90-8.20)	8.20±0.07 (7.90-8.40)	8.27±0.01 (8.25-8.30)
Apr.	8.08±0.03 (8.00-8.10)	8.10±0.07 (7.90-8.20)	8.00±0.07 (7.80-8.10)	8.00±0.01 (8.00-8.05)	8.22±0.01 (8.20-8.25)
May	8.07±0.02 (8.00-8.10)	8.10±0.04 (8.05-8.25)	8.07±0.06 (8.00-8.15)	8.07±0.03 (8.00-8.10)	8.17±0.86 (8.05-8.20)
Jun.	8.14±0.18 (7.75-8.60)	7.98±0.22 (7.55-8.60)	7.98±0.22 (7.42-8.45)	8.36±0.32 (7.85-9.30)	8.04±0.17 (7.75-8.55)
Jul.	8.42±0.14 (8.40-8.45)	8.31±0.05 (8.10-8.38)	8.20±0.11 (8.00-8.45)	8.38±0.21 (8.10-9.00)	8.30±0.07 (8.10-8.40)
Aug.	8.14±0.09 (7.85-8.40)	8.10±0.07 (7.95-8.35)	7.95±0.12 (7.60-8.35)	8.14±0.12 (7.75-8.40)	8.16±0.06 (8.00-8.35)
Sep.	8.25±0.06 (8.15-8.35)	8.28±0.03 (8.20-8.30)	7.99±0.09 (7.80-8.22)	8.11±0.13 (7.70-8.30)	8.28±0.03 (8.20-8.35)
Oct.	8.27±0.07 (8.20-8.30)	8.22±0.05 (8.05-8.30)	8.00±0.16 (7.40-8.40)	8.10±0.02 (8.05-8.15)	8.23±0.03 (8.12-8.30)
Nov.	8.23±0.03 (8.15-8.30)	8.11±0.17 (7.82-8.25)	8.11±0.13 (7.82-8.38)	8.06±0.00 (7.90-8.25)	8.17±0.04 (8.10-8.25)
Dec.	8.21±0.02 (8.15-8.25)	8.26±0.03 (8.15-8.30)	8.03±0.12 (7.60-8.20)	8.12±0.01 (8.20-8.25)	8.28±0.25 (8.20-8.35)
Jan.	8.33±0.01 (8.30-8.35)	8.38±0.01 (8.35-8.40)	8.35±0.17 (8.01-8.90)	8.33±0.01 (8.30-8.35)	8.37±0.01 (8.35-8.38)
Feb.	8.23±0.03 (8.16-8.30)	8.25±0.03 (8.18-8.32)	8.21±0.08 (7.95-8.32)	8.18±0.06 (8.06-8.30)	8.29±0.02 (8.25-8.32)

Figure 5 : Surface water pH of Tolo Harbour, 1971-72

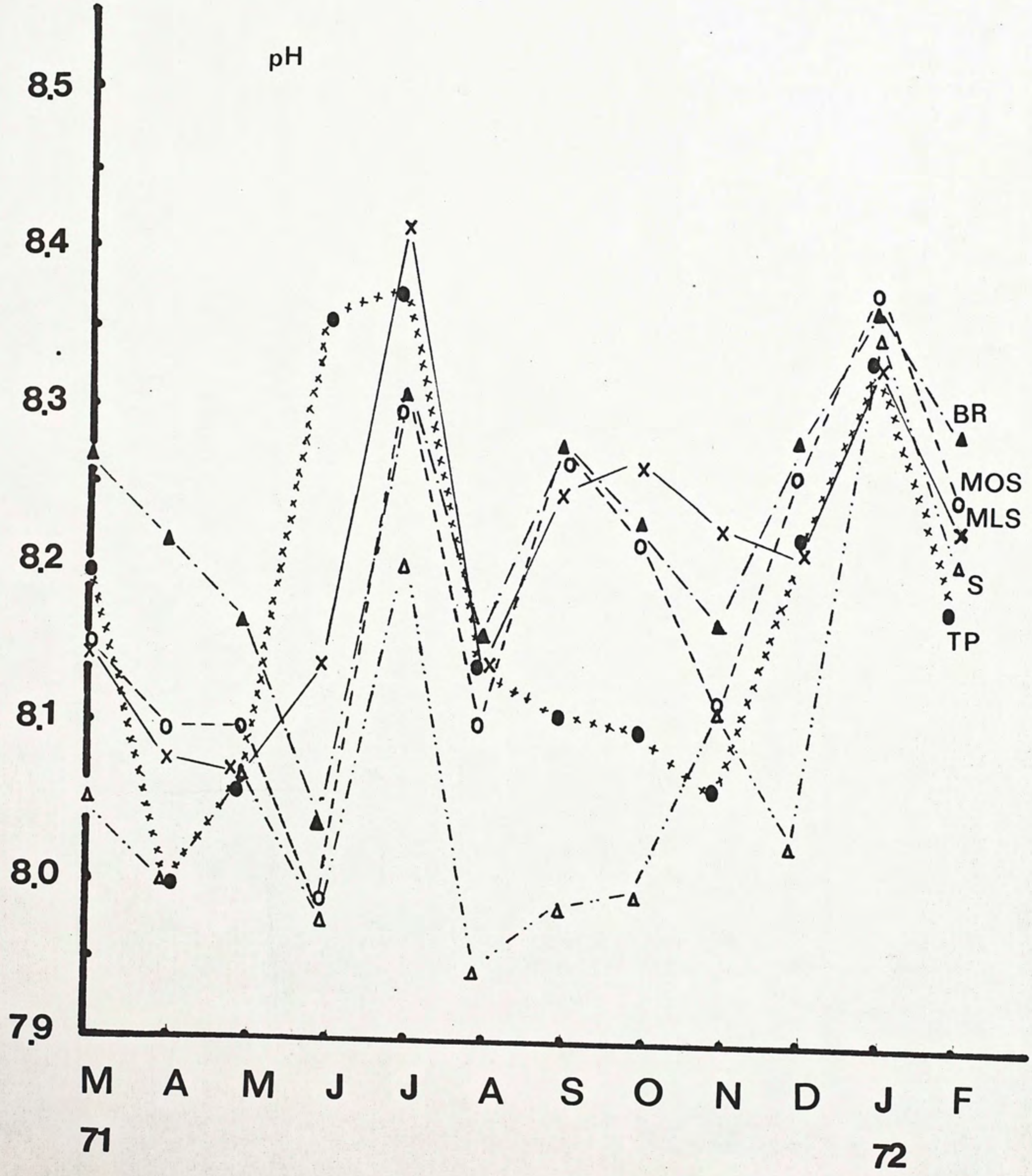


Table V : Surface water dissolved oxygen of Tolo Harbour, 1971-72 (mg./L.)

Month \ Place	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	6.13±0.16 (5.08-7.25)	4.86±0.63 (3.70-5.75)	4.21±0.61 (2.48-5.43)	5.60±0.13 (5.26-5.83)	7.43±0.81 (6.80-8.06)
Apr.	5.37±0.35 (4.35-5.97)	5.00±0.47 (4.20-6.25)	4.08±0.27 (3.50-4.76)	4.60±0.34 (4.21-5.03)	6.33±0.52 (5.09-7.55)
May	5.47±0.42 (4.75-6.67)	5.43±0.25 (4.58-6.01)	5.38±0.56 (4.25-7.48)	4.98±0.65 (3.20-7.25)	5.80±0.35 (5.08-6.94)
Jun.	4.83±0.17 (4.56-5.30)	5.16±0.26 (4.66-5.62)	5.69±1.00 (3.71-8.47)	5.99±0.59 (4.51-7.35)	5.32±0.19 (4.95-5.82)
Jul.	3.57±0.32 (3.10-4.50)	4.73±0.22 (4.35-5.50)	4.53±0.50 (3.47-6.02)	4.33±0.65 (2.54-5.31)	4.51±0.15 (4.18-4.82)
Aug.	4.37±0.43 (3.45-5.77)	5.27±0.59 (3.84-7.07)	4.13±0.31 (3.33-5.20)	3.54±0.26 (3.15-4.40)	5.17±0.42 (3.98-6.84)
Sep.	4.69±0.58 (2.30-4.95)	4.41±0.58 (3.10-5.56)	3.51±0.48 (2.53-4.73)	3.65±0.16 (2.30-5.05)	4.75±0.23 (3.10-6.23)
Oct.	5.47±0.48 (4.03-6.68)	5.32±0.59 (3.40-6.61)	4.94±0.19 (3.30-6.40)	4.95±0.53 (3.10-5.75)	5.68±0.60 (3.85-6.85)
Nov.	5.78±0.29 (4.95-6.25)	5.92±0.10 (5.75-6.20)	4.93±0.45 (3.68-5.80)	5.61±0.16 (4.68-6.12)	5.26±0.51 (4.27-6.32)
Dec.	7.14±0.51 (5.54-8.75)	7.66±0.33 (7.26-8.60)	6.71±0.68 (5.10-8.85)	6.82±0.79 (4.47-9.10)	7.25±0.39 (6.10-8.35)
Jan.	8.83±0.48 (7.75-10.00)	9.32±0.51 (7.90-10.20)	8.46±1.09 (5.60-10.50)	8.41±0.45 (7.60-9.15)	9.33±0.34 (8.42-10.00)
Feb.	7.85±0.38 (6.90-8.90)	7.45±0.13 (7.28-7.86)	6.47±0.66 (5.20-8.18)	6.59±0.51 (5.60-7.21)	7.80±0.32 (6.85-8.22)

Figure 6 : Surface water dissolved oxygen of Tolo Harbour, 1971-72

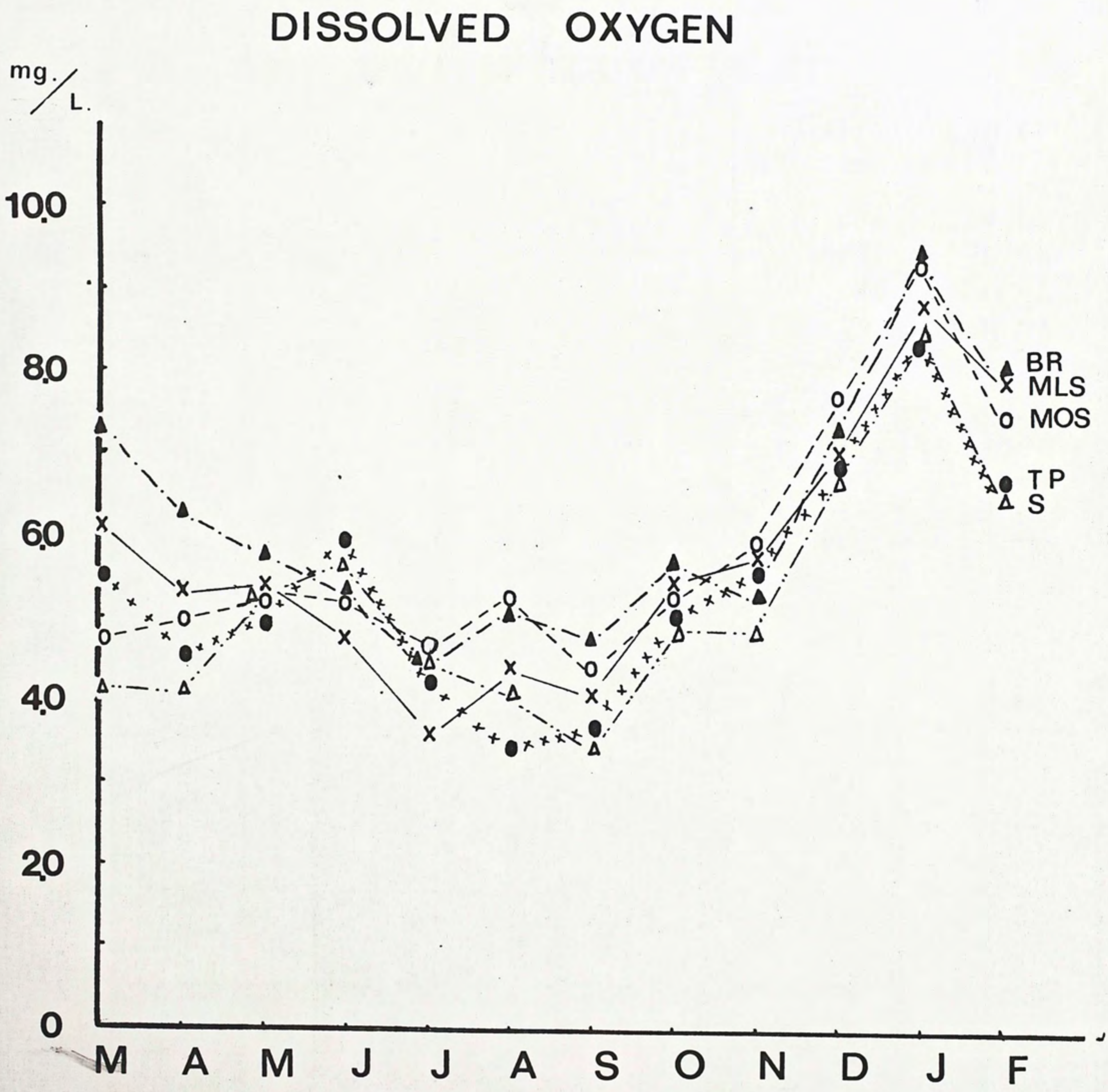
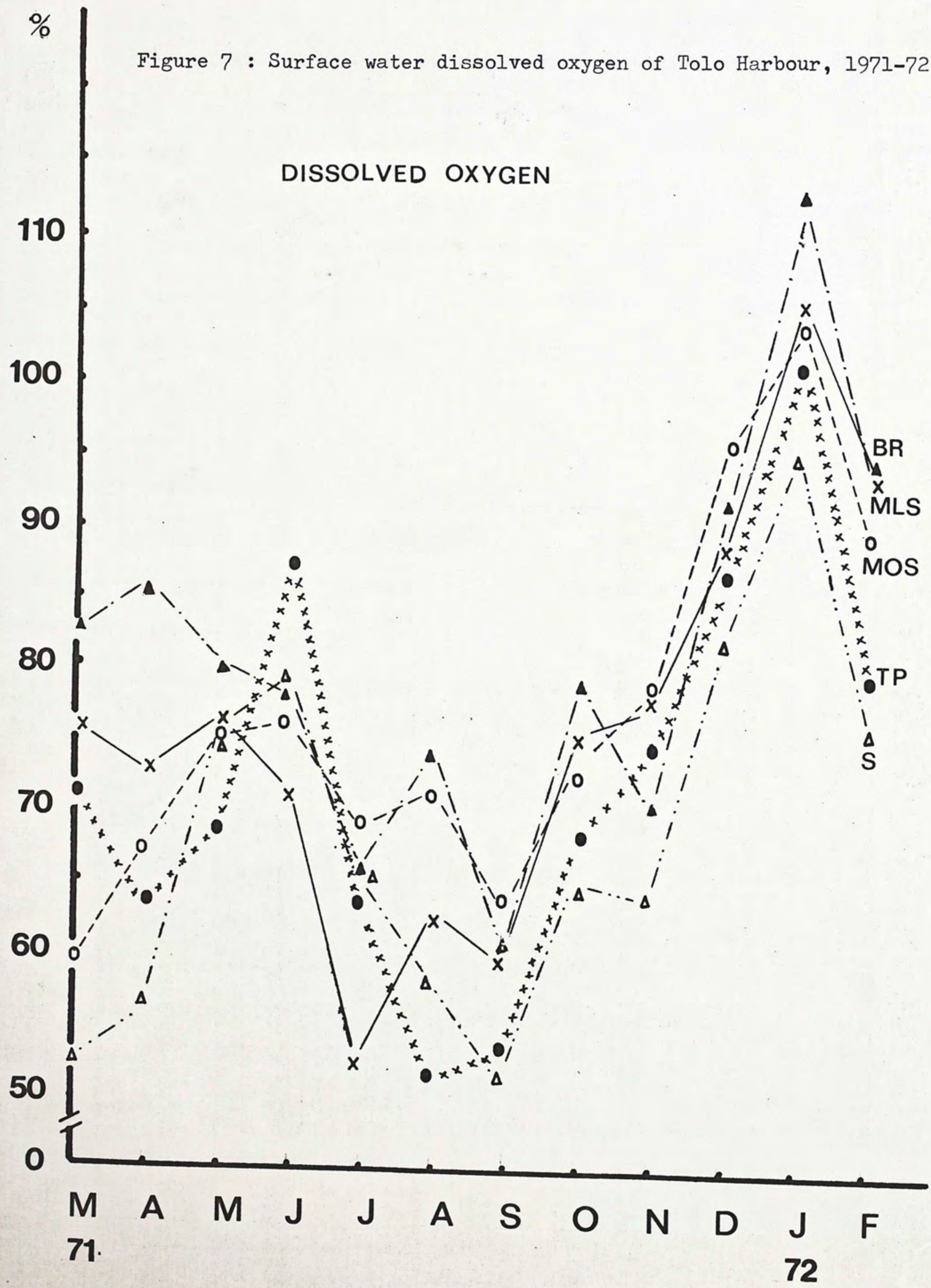


Table VI : Surface dissolved oxygen of Tolo Harbour, 1971-72 (% of saturation)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	75.9±7.0 (64.7-94.0)	59.3±6.2 (45.1-73.8)	52.5±7.4 (31.7-66.1)	71.0±1.1 (67.6-73.6)	82.7±3.6 (77.7-87.8)
Apr.	72.8±4.6 (59.6-80.0)	67.5±7.4 (56.9-83.4)	56.0±3.7 (48.4-65.0)	63.4±3.3 (56.9-72.0)	86.0±7.6 (67.4-103.5)
May	76.5±5.2 (65.9-90.2)	75.2±2.9 (68.4-83.7)	75.5±8.0 (57.3-111.3)	69.0±8.8 (43.9-97.7)	80.4±4.9 (69.7-95.5)
Jun.	71.5±4.9 (67.2-80.1)	76.1±4.2 (68.7-84.1)	79.8±1.1 (53.8-107.0)	87.7±9.3 (66.4-111.7)	78.2±1.8 (73.7-82.4)
Jul.	52.7±4.3 (46.5-65.7)	69.1±2.8 (65.8-77.5)	65.8±7.0 (50.2-83.7)	63.4±9.3 (37.6-77.5)	66.1±1.9 (63.0-70.8)
Aug.	63.3±6.7 (48.4-88.4)	71.6±8.9 (53.7-104.1)	58.7±5.0 (46.3-76.6)	51.5±3.8 (42.8-63.9)	74.7±8.5 (53.1-104.2)
Sep.	59.9±7.5 (36.0-72.6)	63.7±7.9 (45.6-79.2)	51.6±6.2 (37.4-71.0)	53.4±7.1 (33.0-71.7)	60.9±8.7 (46.4-88.8)
Oct.	75.5±7.6 (57.2-94.6)	73.6±7.3 (48.2-92.4)	65.5±6.9 (45.5-80.9)	68.8±7.3 (42.5-81.6)	79.2±8.1 (55.0-95.8)
Nov.	77.4±3.7 (68.5-86.3)	78.6±2.3 (73.8-81.6)	64.3±5.1 (50.4-72.6)	74.9±4.6 (63.7-85.2)	70.5±12.7 (55.8-87.5)
Dec.	88.8±6.0 (69.1-107.4)	95.8±2.5 (89.7-105.9)	82.1±8.0 (63.4-107.6)	86.2±9.8 (57.4-115.0)	91.9±4.5 (79.4-105.0)
Jan.	106.0±4.7 (95.0-117.7)	105.7±7.4 (95.0-102.7)	95.5±11.1 (67.6-118.1)	101.8±2.7 (93.2-108.0)	112.8±3.7 (102.8-120.3)
Feb.	94.0±3.5 (83.3-101.0)	89.8±3.3 (82.2-98.0)	76.1±5.9 (62.2-83.9)	79.7±11.2 (61.8-89.8)	93.9±3.6 (82.3-100.9)

Figure 7 : Surface water dissolved oxygen of Tolo Harbour, 1971-72



The monthly averages were all greater than 50% saturation though in a number of instances the percentage dissolved oxygen was well below this figure (Table V and VI).

From Figures 6 and 7, it can be seen that differences between the stations are apparent. Bush Reef always had the higher dissolved oxygen values, Ma Liu Shui and Ma On Shan had less, while the dissolved oxygen values of the water at Shatin and Tai Po were often lower. The annual means are given in Table XIV.

6. Phosphate :

The phosphate-phosphorus concentration in the sea water of the various stations fluctuated considerably. However, as shown in Table VII and Figure 8, the phosphate concentrations in the surface water at Tai Po and Shatin were always higher and those at Bush Reef lower than the other stations. This is best known in the annual mean values (Table XV). On the whole, higher values were experienced in the hot months.

7. Nitrate :

Similar results as those obtained for the phosphate estimates were recorded. In Shatin and Tai Po the water contained a high concentration of nitrate-nitrogen (Table VIII and Figure 9).

On the other hand, the nitrate content of the water at Bush Reef was always lower compared with the other stations (Table XV).

8. Coliform Bacteria :

(a) Water:

Coliform bacteria were found to be present in Tolo Harbour by the

Table VII : Phosphate-phosphorus of Tolo Harbour, 1971-72 (μg.a/L.)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	0.35±0.07 (0.21-0.48)	0.38±0.05 (0.26-0.53)	0.66±0.09 (0.42-0.86)	0.93±0.11 (0.77-1.22)	0.41±0.06 (0.35-0.48)
Apr.	0.40±0.05 (0.26-0.48)	0.39±0.04 (0.34-0.51)	0.63±0.04 (0.62-0.63)	0.72±0.09 (0.53-0.78)	0.34±0.04 (0.34-0.40)
May	0.26±0.03 (0.21-0.34)	0.43±0.07 (0.29-0.63)	0.50±0.08 (0.44-0.60)	0.50±0.08 (0.34-0.60)	0.26±0.01 (0.21-0.32)
Jun.	0.63±0.11 (0.39-0.92)	0.29±0.07 (0.10-0.39)	0.47±0.13 (0.27-0.78)	0.40±0.04 (0.29-0.48)	0.21±0.05 (0.05-0.35)
Jul.	0.69±0.16 (0.38-1.07)	0.49±0.06 (0.19-1.07)	0.87±0.24 (0.39-1.45)	0.88±0.29 (0.39-1.64)	0.35±0.13 (0.30-0.77)
Aug.	0.58±0.10 (0.26-0.87)	0.62±0.10 (0.55-0.71)	0.68±0.04 (0.55-0.70)	0.75±0.11 (0.63-0.90)	0.38±0.06 (0.24-0.55)
Sep.	1.00±0.25 (0.58-1.76)	0.61±0.15 (0.22-0.90)	0.81±0.23 (0.18-1.25)	1.40±0.44 (0.38-2.76)	1.11±0.52 (0.32-2.82)
Oct.	0.87±0.43 (0.18-2.11)	0.70±0.29 (0.10-1.35)	0.99±0.42 (0.13-2.15)	1.16±0.51 (0.27-3.10)	0.67±0.23 (0.13-1.42)
Nov.	0.24±0.08 (0.14-0.42)	0.15±0.04 (0.09-0.28)	0.12±0.20 (0.69-1.45)	1.20±0.34 (0.13-1.56)	0.16±0.04 (0.09-0.27)
Dec.	0.32±0.05 (0.20-0.45)	0.60±0.09 (0.32-0.85)	0.42±0.04 (0.28-0.52)	0.48±0.04 (0.37-0.58)	0.50±0.22 (0.23-0.78)
Jan.	0.26±0.12 (0.09-0.62)	0,14±0.03 (0.08-0.21)	0.70±0.35 (0.09-1.60)	0.56±0.31 (0.04-1.65)	0.09±0.03 (0.05-0.18)
Feb.	0.41±0.04 (0.32-0.54)	0.33±0.06 (0.04-0.42)	0.35±0.05 (0.23-0.47)	0.70±0.12 (0.41-1.19)	0.25±0.05 (0.13-0.37)

Figure 8 : Phosphate-phosphorus of Tolo Harbour, 1971-72

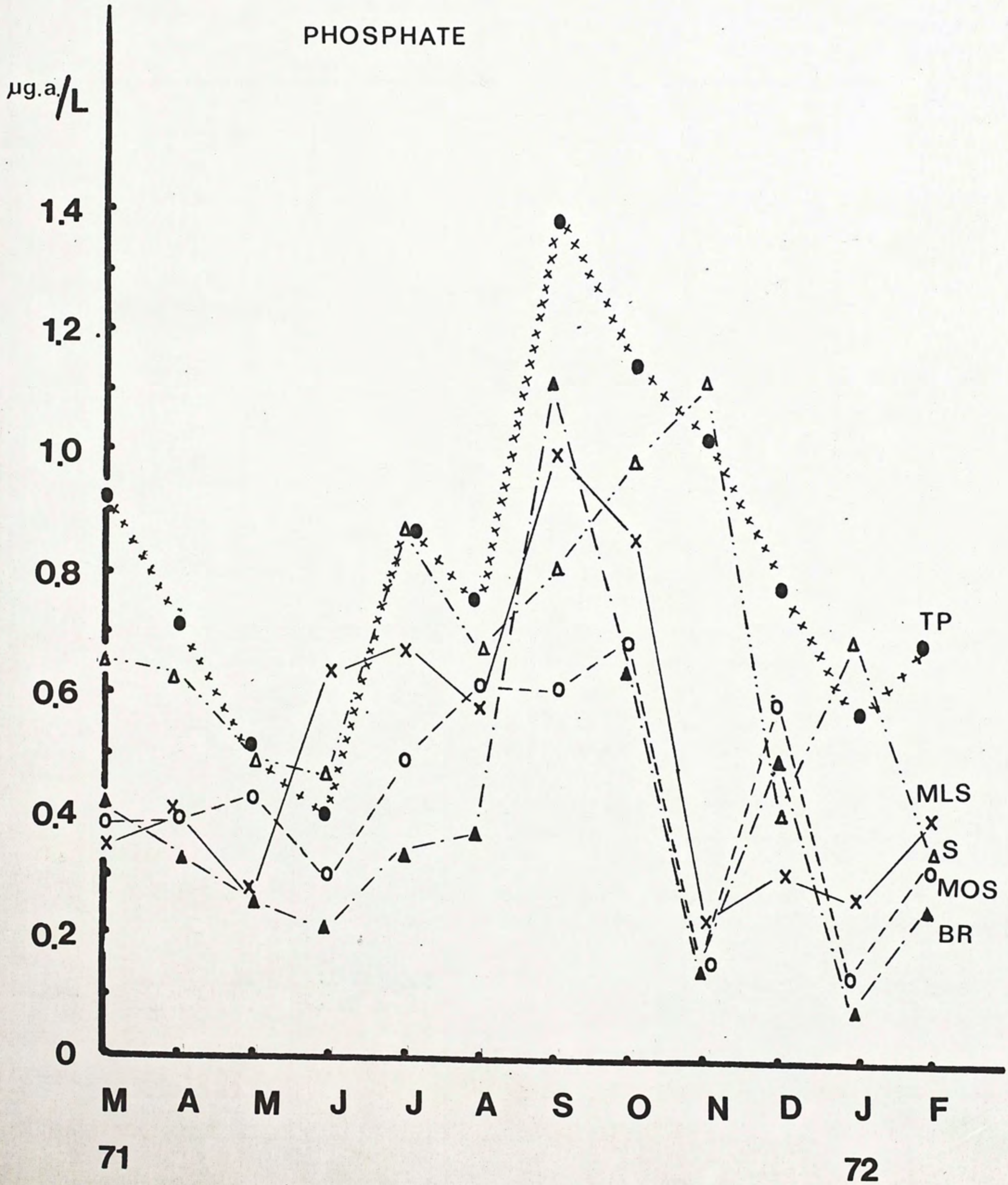
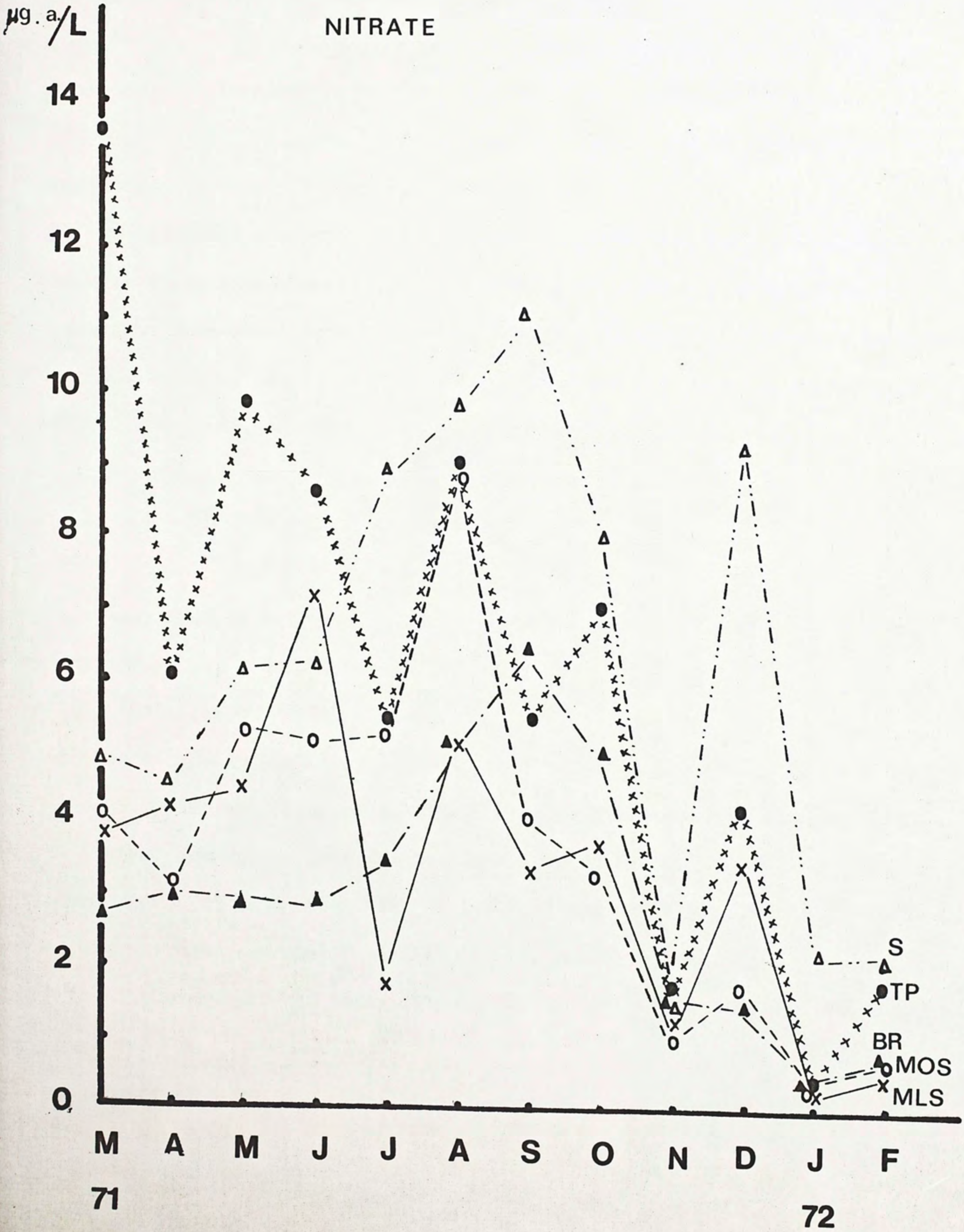


Table VIII : Nitrate-nitrogen of Tolo Harbour, 1971-72 (μg.a/L.)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	3.78±0.37 (0.44-5.00)	4.11±0.21 (3.71-4.67)	9.52±0.43 (8.71-10.50)	13.66±3.60 (7.26-20.48)	2.66±0.20 (2.02-3.31)
Apr.	4.19±0.60 (2.42-5.00)	3.12±0.66 (2.09-5.03)	4.54±0.61 (3.09-5.78)	5.96±1.72 (2.97-10.03)	2.97±0.44 (1.97-4.03)
May	4.43±0.71 (2.98-6.85)	5.26±0.68 (3.14-6.77)	6.13±0.39 (4.36-9.44)	9.76±1.57 (5.24-14.27)	2.92±0.15 (2.09-3.70)
Jun.	7.23±1.43 (3.63-10.48)	5.08±0.63 (3.42-6.45)	6.20±1.51 (3.63-9.68)	8.73±1.12 (5.65-10.48)	2.76±0.48 (2.01-4.03)
Jul.	1.73±0.66 (1.01-3.63)	5.16±1.39 (1.37-8.06)	8.76±1.73 (3.63-12.17)	5.25±1.46 (1.97-8.07)	3.35±0.45 (2.51-4.23)
Aug.	5.24±0.86 (4.75-10.40)	0.78±0.54 (7.59-10.50)	9.72±1.05 (7.38-13.26)	8.94±0.36 (6.69-10.08)	5.01±0.81 (2.42-7.30)
Sep.	3.32±0.83 (1.01-4.65)	4.04±1.11 (1.32-6.73)	11.02±3.11 (3.46-25.10)	5.44±0.70 (0.68-10.08)	6.33±0.89 (4.42-8.48)
Oct.	3.75±1.57 (0.24-6.75)	3.25±0.90 (0.82-4.93)	7.97±1.37 (4.52-11.28)	6.98±1.77 (2.43-10.82)	4.91±1.10 (1.85-7.80)
Nov.	0.99±0.12 (0.80-1.38)	0.88±0.16 (0.53-1.42)	1.75±0.42 (0.84-2.82)	1.40±0.06 (1.22-1.52)	1.50±0.42 (0.86-2.72)
Dec.	3.40±0.94 (0.28-5.80)	1.69±0.47 (0.38-4.82)	9.24±0.17 (0.18-22.80)	4.26±0.66 (0.15-12.30)	1.40±0.25 (0.98-2.15)
Jan.	0.23±0.11 (0.10-0.52)	0.27±0.13 (0.10-0.68)	2.07±1.44 (0.15-6.35)	0.25±0.14 (0.10-0.68)	0.41±0.15 (0.15-0.85)
Feb.	0.44±0.16 (0.13-0.77)	0.62±0.12 (0.37-0.95)	2.11±0.39 (1.08-2.79)	1.81±0.38 (0.84-2.69)	0.61±0.18 (0.25-0.98)

Figure 9 : Nitrate-nitrogen of Tolo Harbour, 1971-72



presumptive, confirmed and completed tests. Table IX shows the coliform bacteria counts at various stations expressed as MPN per 100 ml. Table X summarizes the results as log MPN and these are plotted in Figure 10.

From Figure 10 it can be seen that there are 3 levels of pollution among the five stations sampled.

The numbers of coliform bacteria at Bush Reef were low, the monthly averages being approximately 10 MPN. Of the 50 tests for coliform bacteria undertaken upon water from Bush Reef, five showed a total absence of bacteria. On the other hand, Shatin and Tai Po were the two places where high counts of MPN were found, the magnitude being in the order of 10^3 to 10^4.

The highest records in two localities were :

Shatin 92,000 (in November)

Tai Po 35,000 (in October)

Water from Ma Liu Shui and Ma On Shan possessed intermediate numbers of bacteria i.e. under 1,000 MPN/100 ml.

(b) Sediments :

The density of coliform bacteria on the bottom sediments are shown in Tables XI - XII and Figures 11. Again, three subgroups can be recognized. The highest counts for coliform bacteria were at Shatin and Tai Po, the lowest counts at Bush Reef, with Ma Liu Shui and Ma On Shan possessed intermediate numbers (see also Table XVI for the annual means).

(c) Horizontal distribution of coliform bacteria in Shatin Hoi and at Tai Po :

Figure 12 shows the sampling stations and the results of the coliform

Table IX : Coliform bacteria in the surface waters of Tolo Harbour 1971-72 (MPN/100 ml.)

Place / Month	Ma Liu Shui	Ma On Shan
	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	8.7±2.8 (4.5-17)	19 ±4.3 (7.8-27)
Apr.	18±2.8 (6.2-44)	34 ±17 (7.3-75)
May	18±4.8 (9.1-34)	56 ±19 (7.3-93)
Jun.	58±25 (11-120)	50 ±33 (11 -150)
Jul.	88±32 (27-170)	99 ±49 (17 -220)
Aug.	84±35 (11-220)	170± 64 (20-350)
Sep.	320±57 (6.8-920)	74±31 (14-160)
Oct.	86±59 (6.1-280)	110±19 (11-280)
Nov.	32±17 (6.8-82)	110±45 (7.8-350)
Dec.	390±320 (2-1600)	740±390 (70-2800)
Jan.	30±9 (11-64)	43±13 (7.8-95)
Feb.	460±27 (2-1100)	16±6.6 (4-36)

Table IX : (continued)

Shatin	Tai Po	Bush Reef
Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
430±260 (93-1200)	1600±210 (140-4600)	34±8 (26-43)
730±140 (530-1100)	950±320 (430-1800)	19±9 (7.3-43)
530±160 (180-1100)	820±220 (280-1500)	11±3.9 (0-26)
710±160 (440-1100)	970±470 (110-2100)	12±2.9 (3.6-17)
2200±510 (1100-3500)	4300±560 (1100-9200)	6.8±1.2 (3.6-12)
8700±3400 (81-16000)	11000±3700 (950-24000)	10±3.5 (4.5-23)
7300±310 (790-16000)	11000±1900 (360-16000)	9.9±3.4 (2-17)
2000±880 (95-5400)	8200±3200 (220-35000)	15±12 (2-58)
29000±2000 (590-92000)	10000±8300 (1700-35000)	10±7.5 (2-33)
26000±16000 (1400-92000)	12000±6900 (1600-24000)	4.6±1.9 (0-11)
31000±20000 (220-92000)	6800±5700 (390-24000)	4±1.6 (0-78)
30000±8800 (16000-54000)	19000±8100 (9200-35000)	11±1.2 (0-33)

Table X : Coliform bacteria in the surface waters of Tolo Harbour, 1971-72 (log MPN)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	0.88±0.12 (9.65-1.23)	1.24±0.12 (0.89-1.43)	2.44±0.23 (1.97-3.08)	2.85±0.34 (2.15-3.66)	1.52±0.04 (1.42-1.63)
Apr.	1.13±0.19 (0.79-1.64)	1.15±0.16 (0.86-1.45)	2.84±0.07 (2.72-3.04)	2.89±0.15 (2.63-3.26)	1.17±0.17 (0.86-1.63)
May	1.20±0.11 (0.96-1.53)	1.54±0.28 (0.86-1.97)	2.64±0.13 (2.26-3.04)	2.84±0.13 (2.45-3.18)	0.78±0.26 (0.00-1.42)
Jun.	1.60±0.23 (1.04-2.08)	1.44±0.25 (1.04-2.18)	2.82±0.08 (2.64-3.04)	2.73±0.30 (2.04-3.32)	1.01±0.15 (0.56-1.23)
Jul.	1.84±0.18 (1.43-2.23)	1.75±0.29 (1.23-2.34)	3.29±0.11 (3.04-3.54)	3.50±0.20 (3.04-3.96)	0.79±0.11 (0.57-1.08)
Aug.	1.74±0.21 (1.04-2.34)	1.97±0.27 (1.30-2.54)	3.51±0.43 (1.91-4.20)	3.84±0.23 (2.98-4.38)	0.92±0.12 (0.65-1.36)
Sep.	2.27±0.23 (1.83-2.96)	1.73±0.22 (1.15-2.20)	3.67±0.28 (2.90-4.20)	3.76±0.40 (2.56-4.20)	0.87±0.29 (0.30-1.23)
Oct.	1.61±0.23 (0.79-2.45)	1.71±0.30 (1.04-2.45)	3.01±0.29 (1.98-3.73)	3.25±0.39 (2.34-4.54)	0.76±0.27 (0.30-1.76)
Nov.	1.30±0.24 (0.83-1.91)	1.58±0.35 (0.89-2.54)	4.96±0.79 (2.77-4.96)	3.62±0.31 (3.23-4.54)	0.69±0.29 (0.30-1.52)
Dec.	1.83±0.38 (0.30-3.20)	2.51±0.26 (1.85-3.45)	3.93±0.35 (3.15-4.96)	3.86±0.25 (3.20-4.38)	0.50±0.22 (0.00-1.04)
Jan.	1.37±0.18 (1.04-1.81)	1.47±0.23 (0.89-1.98)	3.92±0.56 (2.34-4.96)	3.39±0.40 (2.59-4.38)	0.44±0.25 (0.00-0.89)
Feb.	2.54±0.42 (0.30-2.04)	1.07±0.20 (0.60-1.57)	4.41±0.13 (4.20-4.73)	4.22±0.13 (3.96-4.54)	0.76±0.31 (0.00-1.52)

Figure 10 : Coliform bacteria in the surface waters of Tolo Harbour

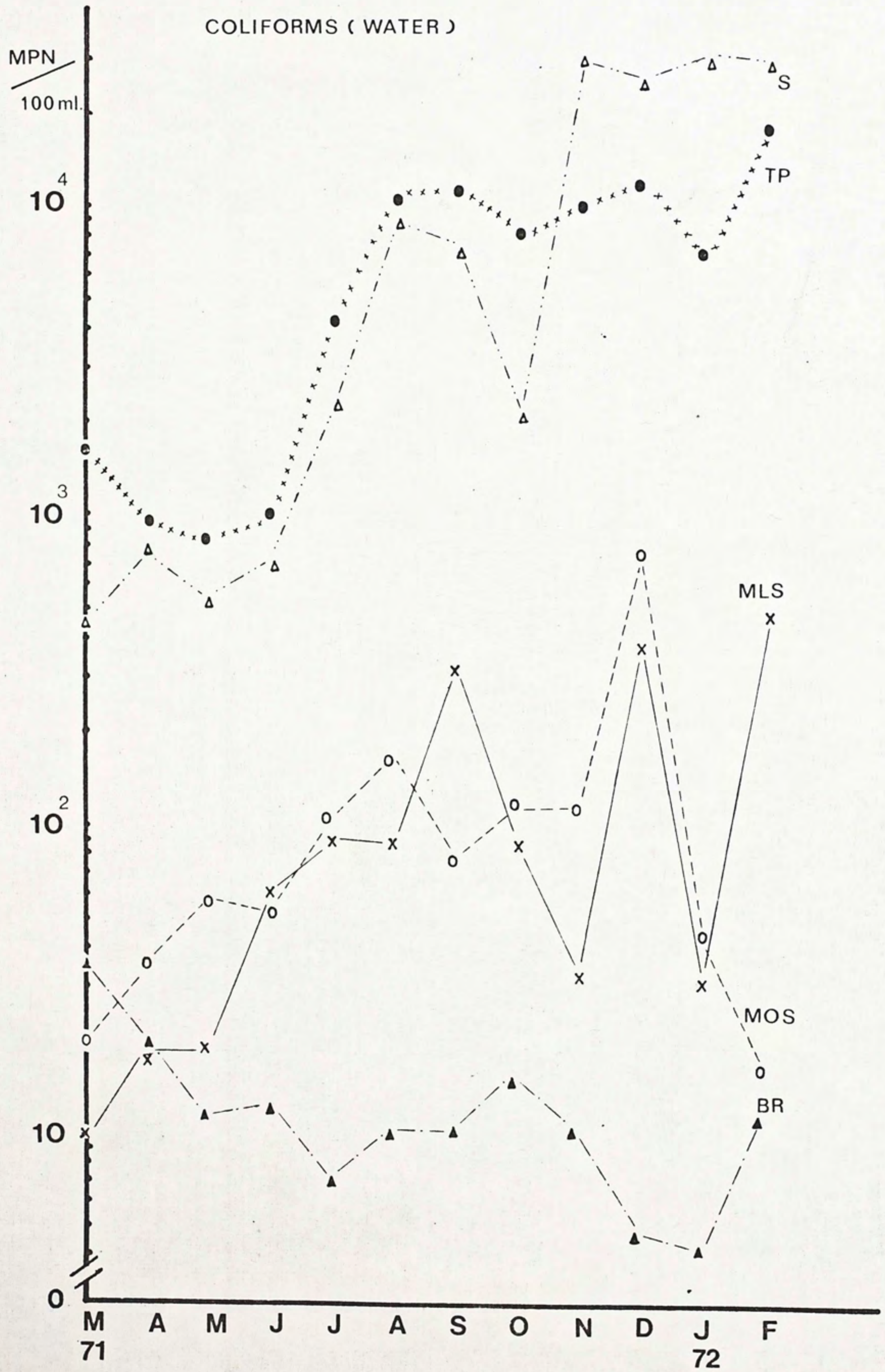


Table XI : Coliform bacteria in the sediments of Tolo Harbour, 1971-72 (MPN/cm^2)

Place / Month	Ma Liu Shui	Ma On Shan
	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	760±220 (390-1300)	380±64 (36-960)
Apr.	1400±760 (80-3500)	3900±1500 (840-6500)
May	200±71 (48-370)	540±110 (370-960)
Jun.	1300±920 (80-3700)	880±98 (640-1100)
Jul.	320±170 (100-840)	4800±2000 (880-9600)
Aug.	2300±1800 (44-9600)	3400±1600 (880-9600)
Sep.	970±400 (220-2100)	2600±270 (720-3700)
Oct.	510±400 (68-2100)	580±410 (84-2100)
Nov.	570±120 (280-880)	2000±1400 (48-6400)
Dec.	750±230 (26-2200)	1300±570 (170-3500)
Jan.	190±80 (27-380)	590±520 (16-2200)
Feb.	190±71 (56-380)	260±91 (17-440)

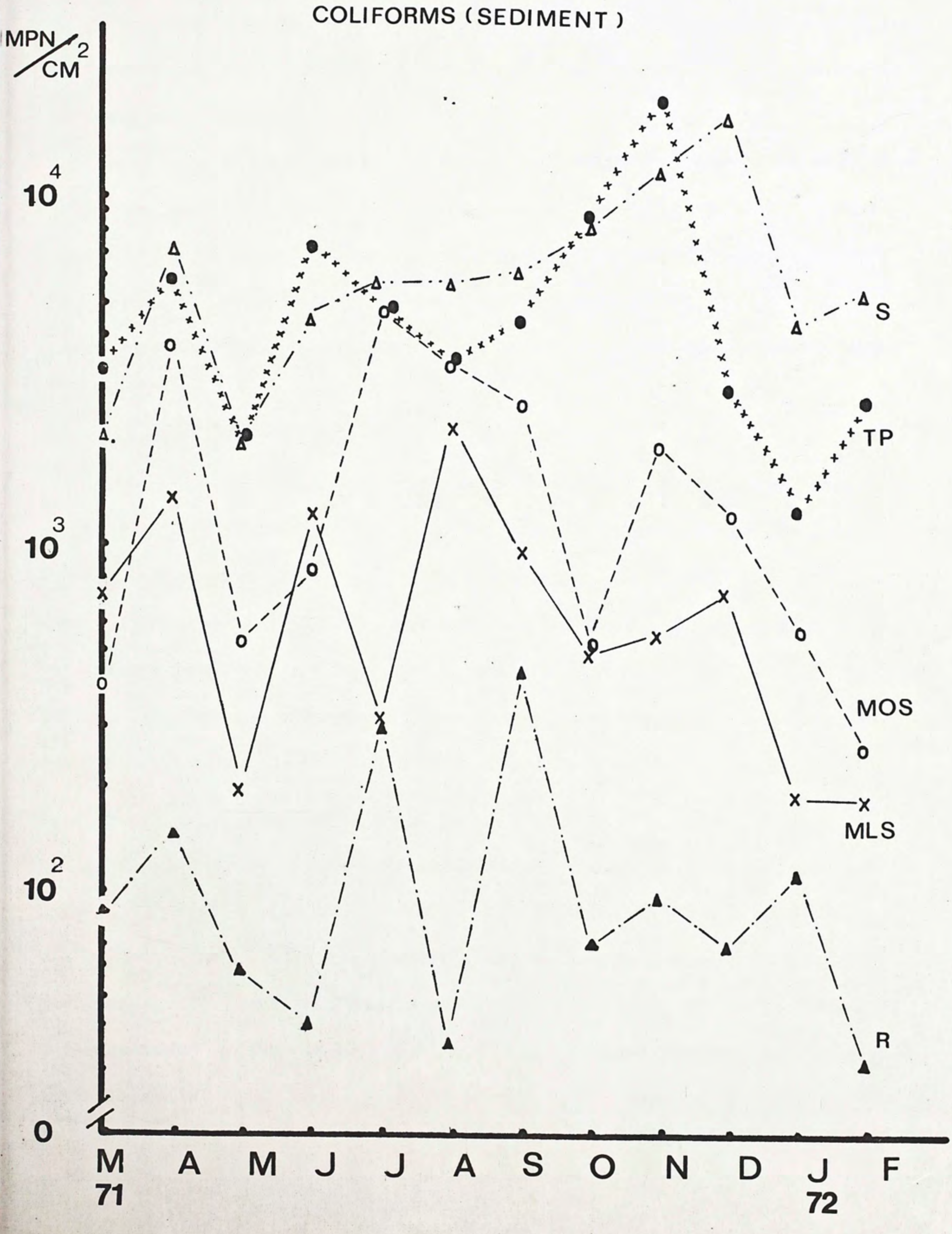
Table XI : (continued)

Shatin	Tai Po	Bush Reef
Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
2100±860 (960-3700)	3200±360 (300-6400)	88±4 (84-92)
7000±1500 (4400-9600)	6100±2100 (840-9600)	150±56 (110-240)
2100±580 (960-4400)	1900±660 (840-4400)	60±13 (24-92)
4700±1100 (1700-6400)	7500±1200 (4400-9600)	43±23 (8-110)
5800±1800 (880-9600)	4800±620 (1400-9600)	310±140 (48-560)
5800±1500 (320-9600)	3400±1200 (1100-6400)	300±200 (84-1100)
6200±500 (4800-7200)	4600±1000 (1300-7200)	470±120 (24-1300)
8300±3400 (880 -21600)	9300±6100 (140-24000)	74±31 (20-184)
12000±8400 (2800-37000)	20000±15000 (2800-64000)	100±73 (20-320)
17000±13000 (248-64000)	2900±1500 (260-6400)	72±23 (9.2-132)
4300±1500 (840-8800)	1300±730 (560-2200)	120±52 (56-270)
5500±3300 (1600-14000)	2700±1200 (1100-6400)	33±11 (17-68)

Table XII : Coliform bacteria in the sediments of Tolo Harbour, 1971-72 (log MPN)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	2.32±0.42 (0.97-3.11)	2.34±0.30 (1.56-2.98)	3.27±0.12 (2.98-3.57)	3.30±0.30 (2.48-3.81)	1.94±0.00 (1.92-1.96)
Apr.	2.84±0.35 (1.90-3.54)	3.45±0.22 (2.92-3.81)	3.81±0.10 (3.64-3.98)	3.63±0.23 (2.92-3.98)	2.21±0.07 (2.05-2.38)
May	2.13±0.16 (1.68-2.57)	2.70±0.08 (2.57-2.98)	3.23±0.11 (2.98-3.64)	3.19±0.13 (2.92-3.64)	1.72±0.11 (1.38-1.96)
Jun.	2.80±0.34 (1.90-3.57)	2.94±0.05 (2.81-3.05)	3.62±0.13 (3.24-3.81)	3.85±0.06 (3.64-3.98)	1.43±0.25 (0.90-2.05)
Jul.	2.33±0.20 (2.02-2.92)	3.51±0.21 (2.95-3.98)	3.63±0.23 (2.95-3.98)	3.54±0.21 (3.15-3.98)	2.27±0.28 (1.68-2.75)
Aug.	2.81±0.48 (2.04-3.98)	3.35±0.19 (2.95-3.98)	3.58±0.27 (2.51-3.98)	3.43±0.13 (3.05-3.81)	2.34±0.23 (1.92-3.04)
Sep.	2.84±0.18 (2.35-3.34)	3.27±0.14 (2.86-3.57)	3.79±0.04 (3.68-3.86)	3.58±0.17 (3.11-3.86)	2.34±0.36 (1.38-3.12)
Oct.	2.30±0.26 (2.02-3.31)	2.31±0.27 (1.75-7.31)	3.74±0.18 (2.96-4.33)	3.53±0.40 (2.15-4.38)	1.70±0.19 (1.30-2.27)
Nov.	2.72±0.10 (2.45-2.95)	2.82±0.43 (1.68-3.81)	3.76±0.27 (3.45-4.57)	3.93±0.30 (3.45-4.81)	1.72±0.27 (1.30-2.51)
Dec.	2.53±0.32 (1.41-3.34)	2.92±0.21 (2.24-3.54)	3.76±0.39 (2.39-4.81)	3.19±0.27 (2.41-3.81)	1.69±0.25 (0.96-2.12)
Jan.	2.03±0.29 (1.43-2.58)	2.11±0.45 (1.20-3.33)	3.50±0.21 (2.92-3.95)	3.04±0.14 (2.75-3.33)	1.99±0.15 (1.75-2.43)
Feb.	2.16±0.18 (1.75-2.58)	2.18±0.33 (1.23-2.64)	3.59±0.20 (3.21-4.15)	3.33±0.16 (3.05-3.81)	1.44±0.14 (1.23-1.83)

Figure 11 : Coliform bacteria in the sediments of Tolo Harbour, 1971-72



bacterial tests in Shing Mun River and Shatin Hoi. There were high concentrations of coliform bacteria in the river. The density of coliform bacteria decreased when the water reached the sea.

There were differences in the density of coliform bacteria at high tide and at low tide (Figures 13 - 16). The numbers of coliform bacteria were lower at high tide. In Shatin Hoi higher coliform bacterial counts were recorded on the western side (Figures 13 and 14). At Tai Po, there were higher concentrations of coliform bacteria in the water nearer to the shore (Figures 15 and 16).

(d) Clam tissues :

Only one test on Anomalodiscus squamosus (Linné) gave a result that was within the satisfactory limit (80 - 100% clean). The other 15 tests on Anomalodiscus squamosus (Linné), Katelysia rumularis (Linné), and Tapes sp. gave indications that the clams were in unsatisfactory or suspicious conditions (0 - 70 % clean). A separate study, begun in September,1971, was carried out by Y.K. Ho, a senior student of Chung Chi College Biology Department. His results (Appendix III) will be discussed later.

9. Biochemical Oxygen Demand : (BOD_5)

The BOD_5 values for the various stations are shown in Table XIII and Figure 17. The BOD_5 of the waters at Shatin was high. The annual average was 3.72 ± 0.22 ppm. Tai Po ranked second. Ma Liu Shui and Ma On Shan in most cases were lower than Shatin and Tai Po. The BOD_5 values at Bush Reef were the lowest. The annual averages for the various stations are tabulated in Table XVII.

Figure 12 : The horizontal distribution of coliform bacteria in Shing Mun River and Shatin Hoi
(on 4th February, 1971)

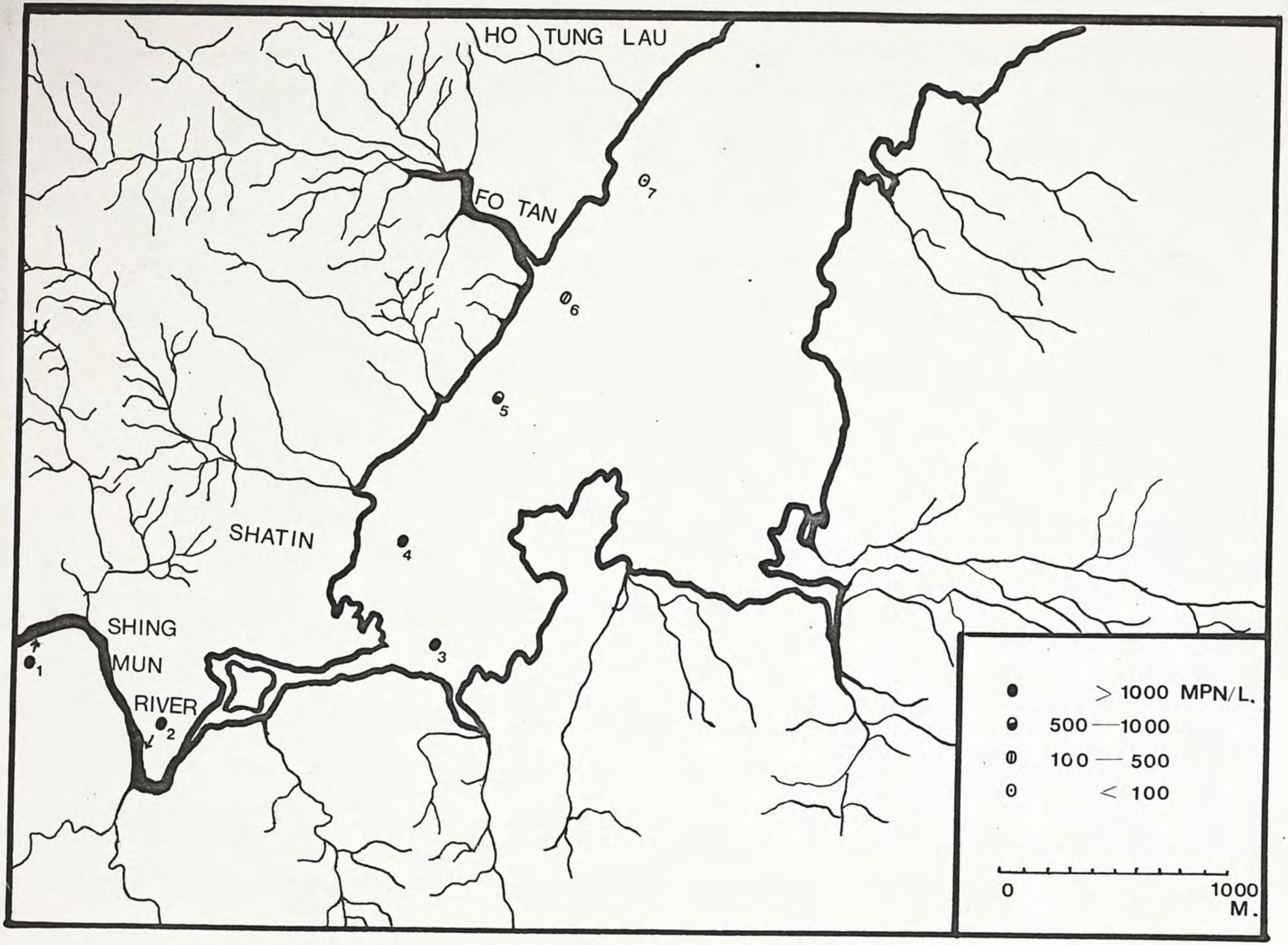


Figure 13 : The horizontal distribution of coliform bacteria in Shatin Hoi at low tide (on 23rd February, 1971)

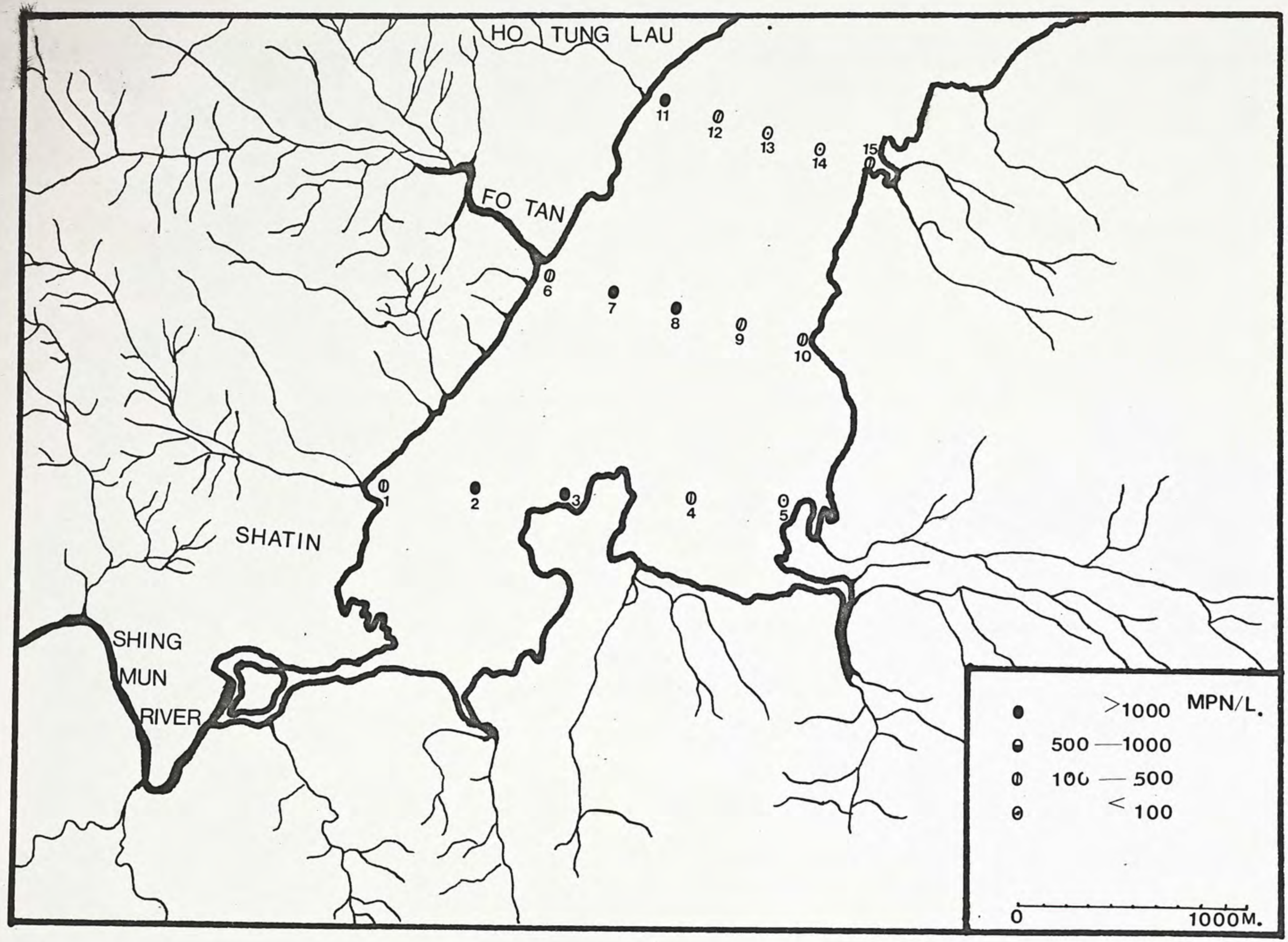


Figure 14 : The horizontal distribution of coliform bacteria in Shatin Hoi at high tide (on 9th March, 1971)

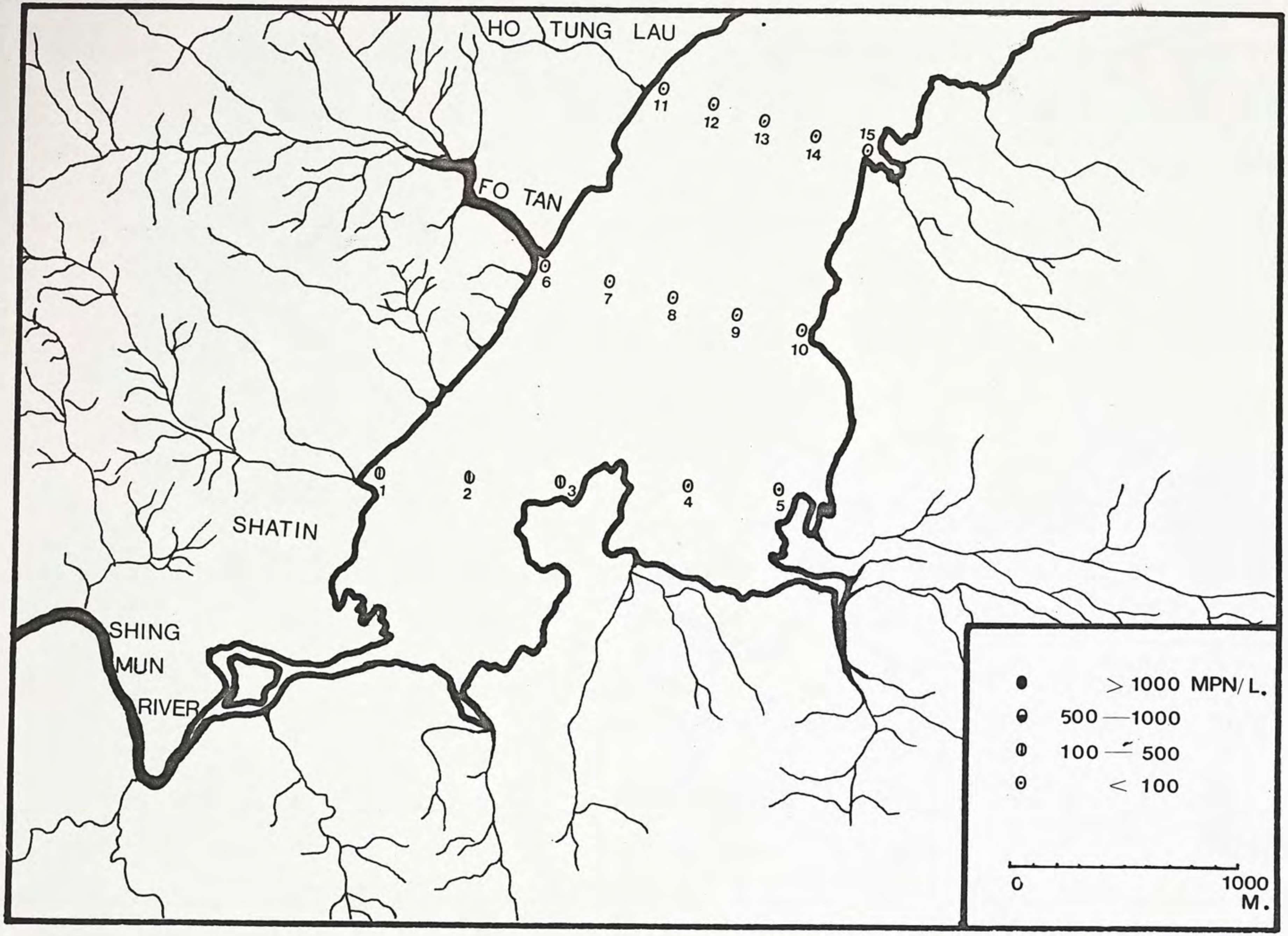


Figure 15 : The horizontal distribution of coliform bacteria at Tai Po at low tide (on 26th February, 1971)

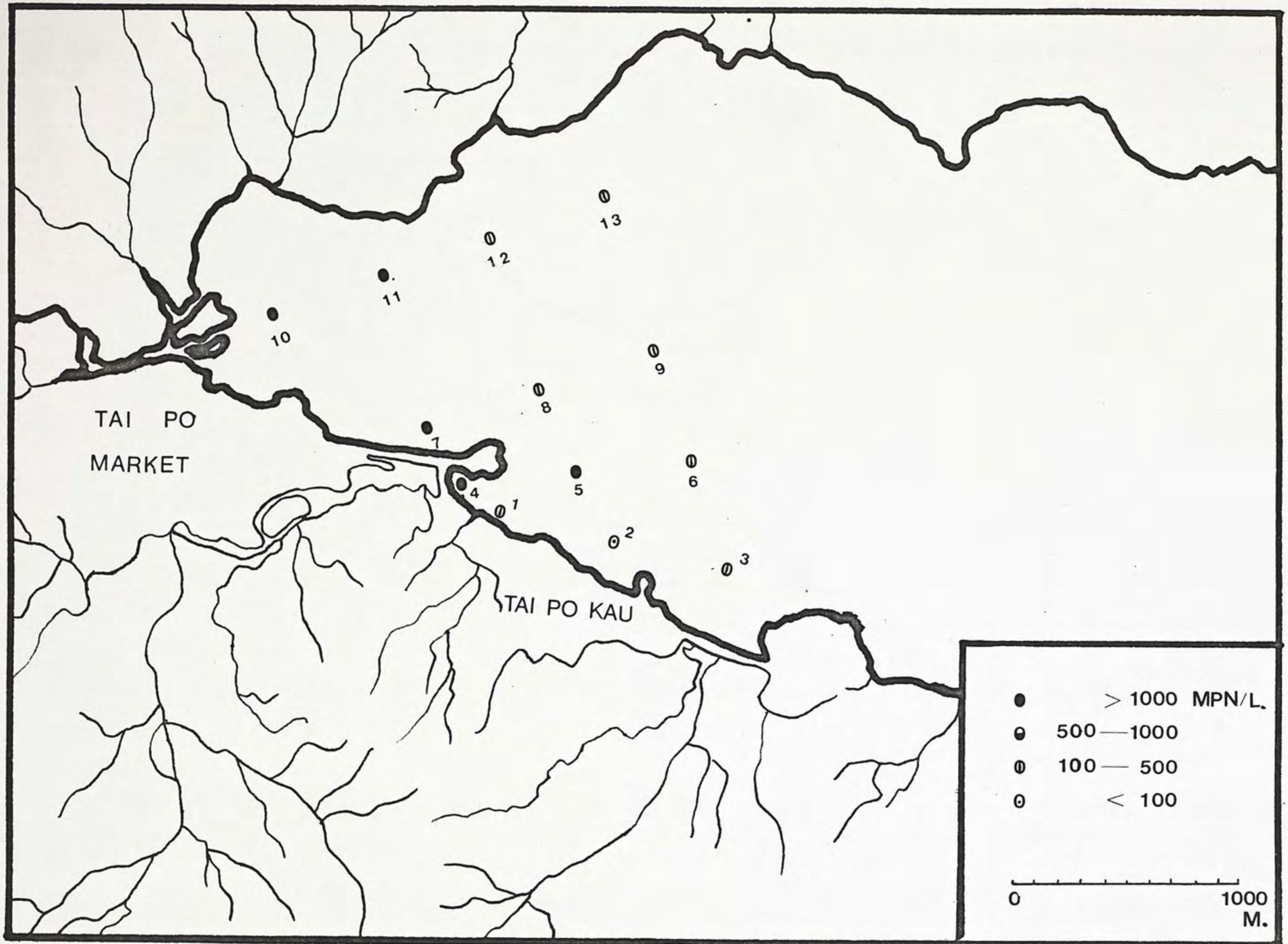


Figure 16 : The horizontal distribution of coliform bacteria at Tai Po at high tide (on 16th March, 1971)

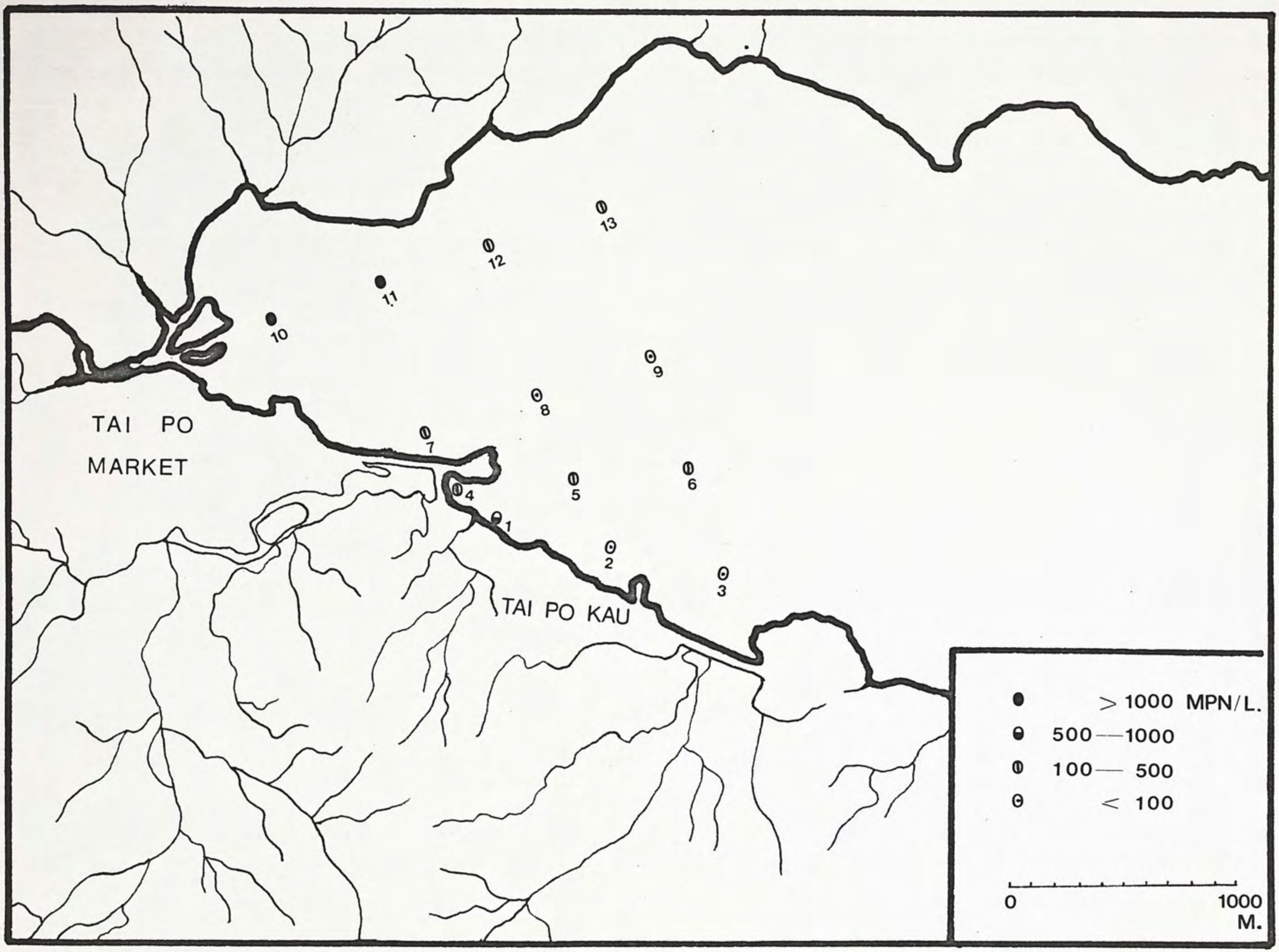


Table XIII : Surface water BOD_5 of Tolo Harbour, 1971-72 (ppm)

Place / Month	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Mar.	1.90±0.29 (1.42-2.78)	1.86±0.38 (1.12-2.91)	3.30±0.27 (2.57-3.86)	2.91±0.29 (2.35-3.70)	1.10±0.13 (0.68-1.57)
Apr.	1.56±0.34 (1.21-2.12)	1.84±0.11 (1.27-2.84)	3.41±0.13 (3.20-3.77)	2.76±0.21 (2.24-3.23)	0.86±0.16 (0.48-1.24)
May	1.79±0.36 (1.08-3.18)	1.85±0.15 (0.97-2.88)	3.53±0.34 (2.49-4.48)	2.25±0.24 (1.85-3.12)	0.79±0.10 (0.42-0.97)
Jun.	1.85±0.54 (0.83-2.83)	1.68±0.08 (1.48-1.83)	3.98±0.14 (2.63-4.59)	3.76±1.18 (1.74-7.01)	1.97±0.78 (0.52-2.89)
Jul.	1.06±0.29 (0.49-1.71)	1.54±0.45 (1.00-2.91)	3.47±0.46 (2.71-4.81)	2.97±0.53 (1.48-3.87)	1.70±0.32 (0.74-2.07)
Aug.	1.67±0.45 (0.90-3.40)	2.02±0.30 (0.92-2.77)	3.14±0.35 (2.02-4.05)	2.48±0.54 (0.77-3.81)	1.82±0.39 (0.33-3.36)
Sep.	1.13±0.14 (0.80-1.45)	1.28+0.24 (0.71-1.86)	3.17±0.51 (1.13-4.44)	3.13±0.31 (2.18-3.77)	0.88±0.14 (0.50-1.10)
Oct.	1.17±0.40 (0.64-1.93)	1.05±0.25 (0.65-1.86)	3.92±0.48 (2.82-5.38)	3.63±0.54 (2.62-5.59)	1.17±0.13 (0.58-1.72)
Nov.	0.88±0.20 (0.56-1.54)	0.88±0.26 (0.43-1.54)	3.30±0.35 (2.44-3.97)	1.94±0.43 (1.22-2.42)	0.74±0.48 (0.48-1.09)
Dec.	1.44±0.18 (1.00-1.95)	1.06±0.08 (0.24-1.65)	3.39±0.65 (0.85-4.50)	2.55±0.29 (1.92-3.08)	0.64±0.13 (0.36-0.97)
Jan.	2.27±0.43 (1.52-3.51)	1.70±0.35 (1.05-2.66)	5.82±0.27 (5.16-6.42)	3.39±0.29 (2.55-3.86)	1.69±0.28 (1.22-2.50)
Feb.	1.81±0.12 (1.04-2.65)	1.30±0.18 (0.86-1.60)	4.26±0.64 (3.00-6.03)	2.81±0.51 (1.30-3.67)	1.40±0.23 (0.86-1.79)

Figure 17 : Surface water BOD_5 of Tolo Harbour, 1971-72

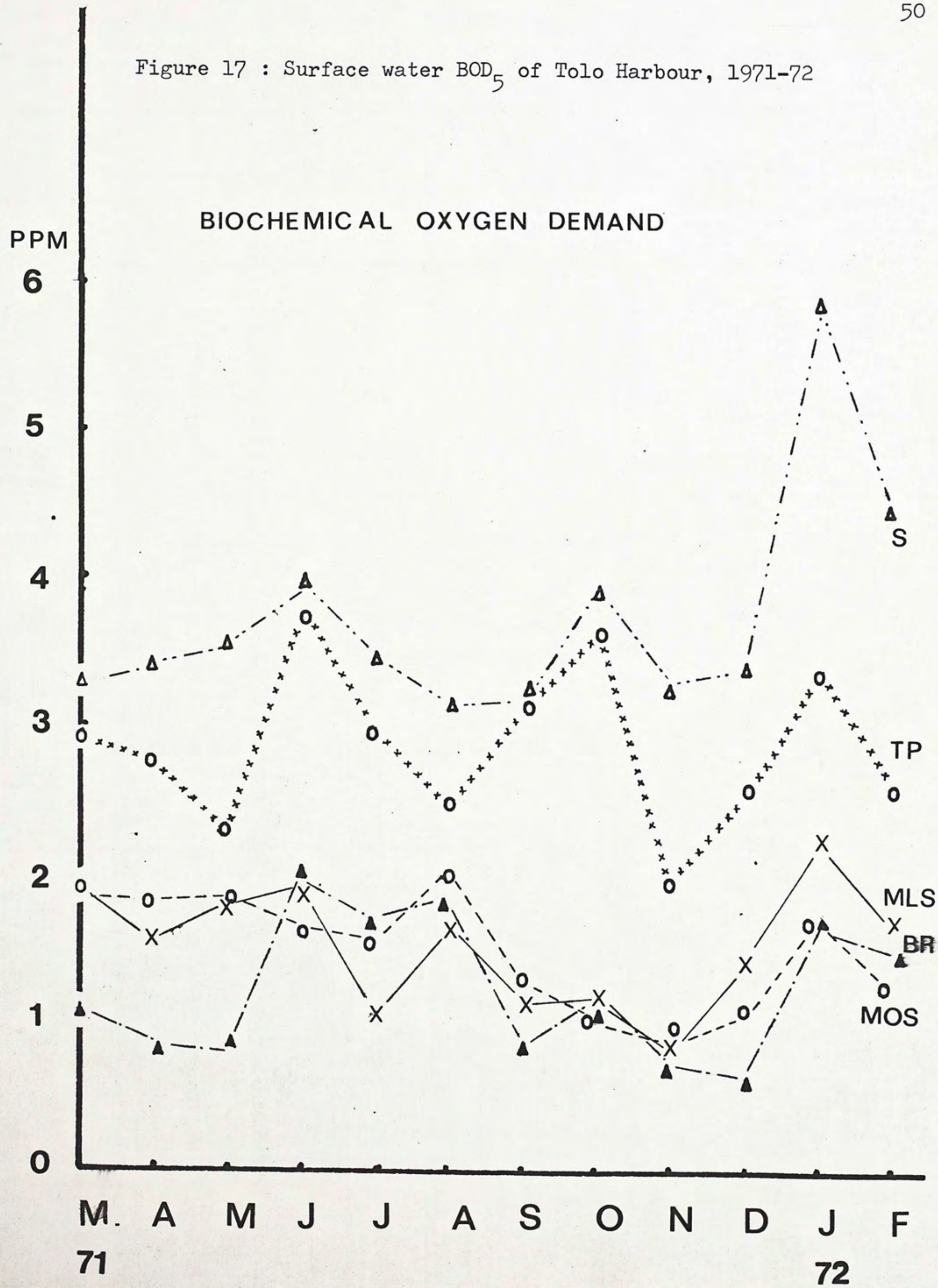


Table XIV : Annual means of hydrological data of Tolo Harbour (March 1971-February 1972)

	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Temperature (°C)	23.6±1.3 (14.0-31.0)	23.4±1.4 (13.6-30.7)	23.5±1.5 (11.6-32.3)	24.1±1.4 (13.5-30.8)	23.9±1.3 (17.8-31.5)
Turbidity (feet)	9.4±0.8 (5.0-20.0)	7.9±0.4 (3.0-14.0)	5.3±0.2 (2.5-9.0)	6.5±0.3 (3.0-25.0)	16.9±0.5 (7.0 -31.0)
Salinity (°/oo)	29.8±0.4 (17.5-32.0)	29.7±0.3 (20.5-33.0)	28.3±0.7 (20.1-32.0)	29.6±0.5 (18.5-32.5)	30.4±0.5 (18.5-34.0)
pH	8.21±0.29 (7.75-8.60)	8.18±0.38 (7.55-8.60)	8.07±0.34 (7.40-8.90)	8.17±0.36 (7.55-9.30)	8.23±0.25 (7.75-8.55)
Dissolved oxygen (mg./L.)	5.74±0.45 (3.57-8.83)	5.87±0.43 (4.41-9.32)	5.25±0.42 (3.61-8.46)	5.42±0.42 (3.54-8.41)	6.21±0.42 (4.51-9.33)
(% saturation)	76.2±8.6 (36.0-117.7)	77.2±11.1 (45.1-120.7)	68.6±11.4 (37.4-118.1)	72.6±12.5 (33.0-115.0)	81.4±8.7 (46.4-120.3)

Figure 18 : Annual means of hydrological data of Tolo Harbour,
(March 1971-February 1972)

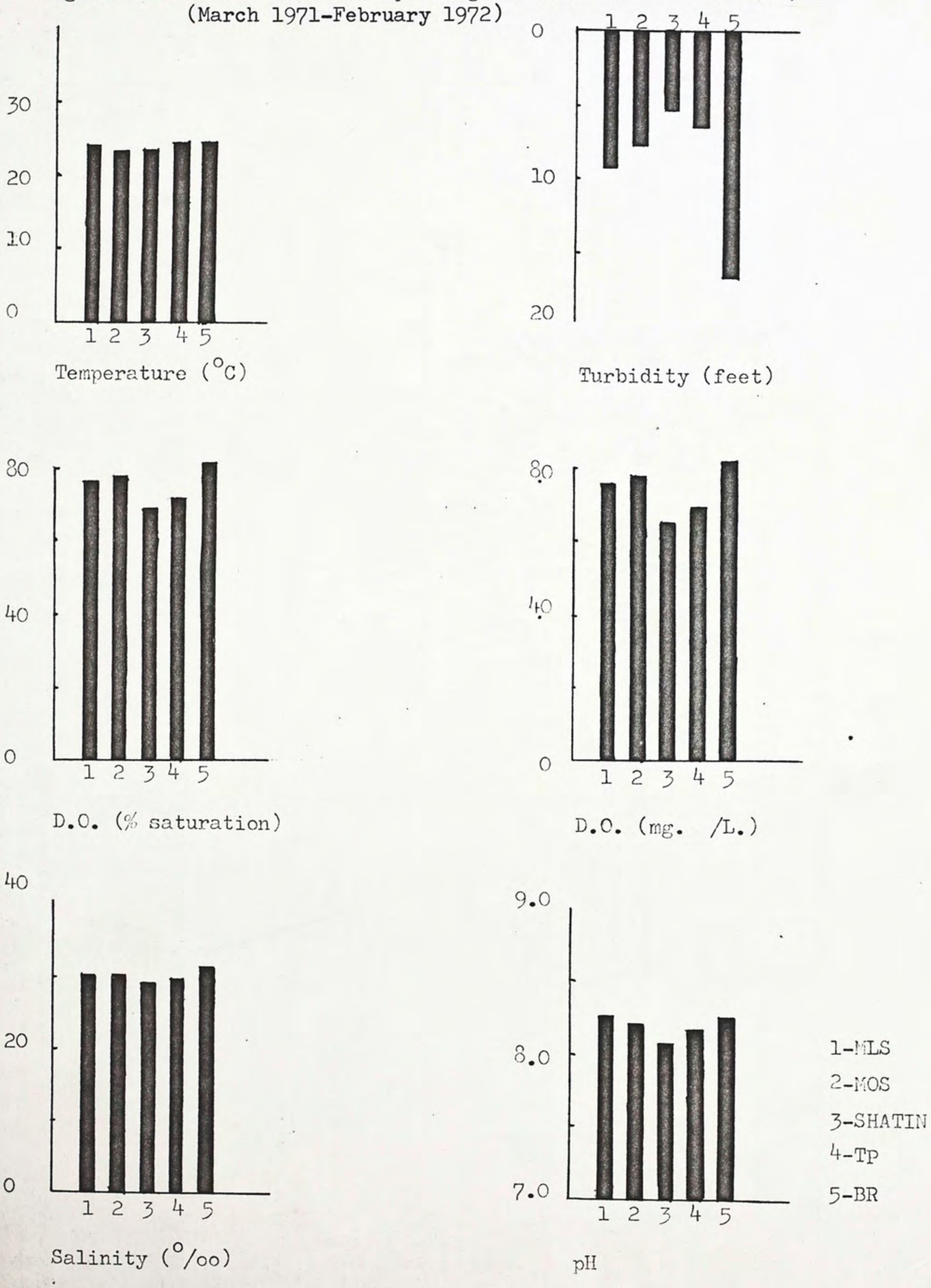


Table XV : Annual means of the nutrients in Tolo Harbour
(March 1971-February 1972)

	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)	Mean±S.E. (Range)
Phosphate -P (µg.a./L.)	0.50±0.07 (0.09-2.11)	0.42±0.05 (0.04-1.35)	0.68±0.07 (0.09-2.15)	0.81±0.08 (0.04-3.10)	0.39±0.08 (0.05-1.42)
Nitrate -N (µg.a./L.)	3.56±0.61 (0.24-10.48)	3.52±0.71 (0.10-10.50)	6.20±1.00 (0.15-25.10)	6.03±1.10 (0.10-20.48)	2.90±5.20 (0.15-8.48)

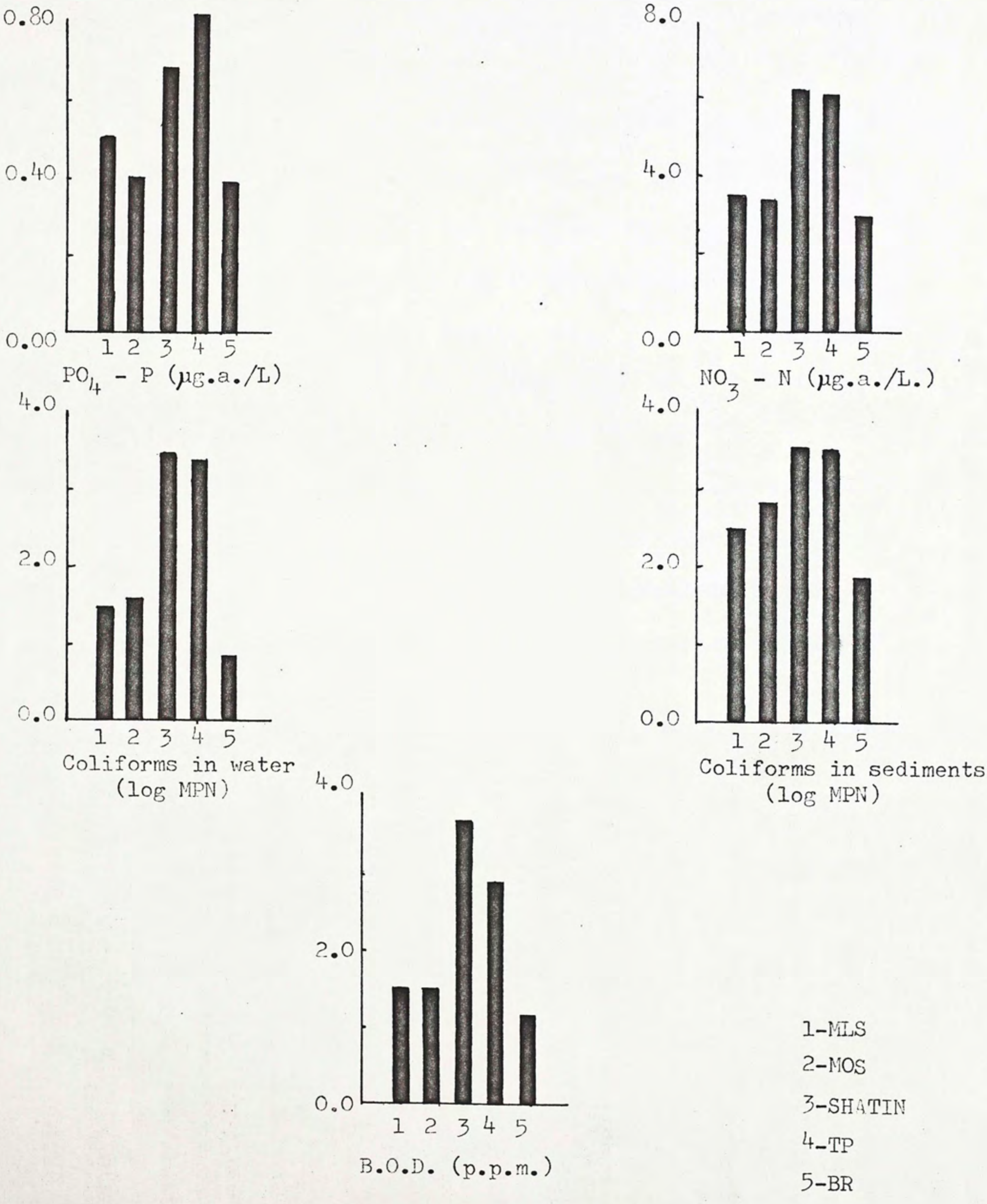
Table XVI : Annual means of coliform bacteria in Tolo Harbour (March 1971-February 1972)

	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
	Mean$\pm$S.E. (Range)	Mean$\pm$S.E. (Range)	Mean$\pm$S.E. (Range)	Mean$\pm$S.E. (Range)	Mean$\pm$S.E. (Range)
Coliforms in water					
MPN 100 ml.	98$\pm$36 (2-1600)	130$\pm$57 (4-2800)	12,000$\pm$3900 (81-92000)	7,400$\pm$1640 (110-35000)	12$\pm$6.7 (0-58)
log MPN	1.50$\pm$0.32 (0.30-3.20)	1.59$\pm$0.33 (0.60-3.45)	3.45$\pm$0.63 (1.91-4.96)	3.38$\pm$0.41 (2.04-4.54)	0.85$\pm$0.23 (0.00-1.76)
Coliforms in sediments					
MPN/cm^2	790$\pm$160 (26-9600)	1800$\pm$452 (16-9600)	6700$\pm$1200 (250-64000)	5600$\pm$1400 (140-64000)	130$\pm$90 (8-1300)
log MPN	2.48$\pm$0.25 (0.91-3.98)	2.82$\pm$0.42 (1.20-7.31)	3.56$\pm$0.16 (2.39-4.57)	3.46$\pm$0.22 (2.15-4.81)	1.89$\pm$0.25 (0.96-3.04)

Table XVII : Annual means of surface water BOD_5 of Tolo Harbour (March 1971-February 1972)

	Ma Liu Shui	Ma On Shan	Shatin	Tai Po	Bush Reef
BOD_5 (p.p.m.)	1.54$\pm$0.11 (0.49-3.40)	1.50$\pm$0.11 (0.24-2.91)	3.72$\pm$0.22 (0.85-6.42)	2.88$\pm$0.15 (0.77-7.01)	1.23$\pm$0.13 (0.64-3.36)

Figure 19 : Annual means of nutrients, coliform bacteria and BOD_5 of Tolo Harbour (March 1971-February 1972)



The dissolved oxygen and BOD_5 for the surface water of 33 stations were taken on 13th May, 1971. The results were used to plot the contour maps in Figures 20 - 21.

As shown in Figure 20, on that particular day, there was a dissolved oxygen gradient extending from Shatin, Ma Liu Shui and Tai Po outward to the middle of the harbour. Shatin, Ma Liu Shui, Tai Po, (and a station near Plover Cove reservoir) were the places in the harbour where the surface water dissolved oxygen was the least.

Figure 21 shows the distribution of surface water BOD_5. On that particular day, high BOD_5 were found at Shatin and Tai Po.

Before this trip, a trip was made on 6th March, 1971 to 29 stations in Tolo Harbour. The results were used to plot the contour map shown in Figure 22. In this figure it can be seen that a high coliform bacterial count was recorded from the sea bottom at Shatin, Ma Liu Shui, Tai Po and from Ma On Shan to a lesser extent.

Figure 20 : Distribution of surface water dissolved oxygen in Tolo Harbour (on 13th May, 1971) (in mg./L.)

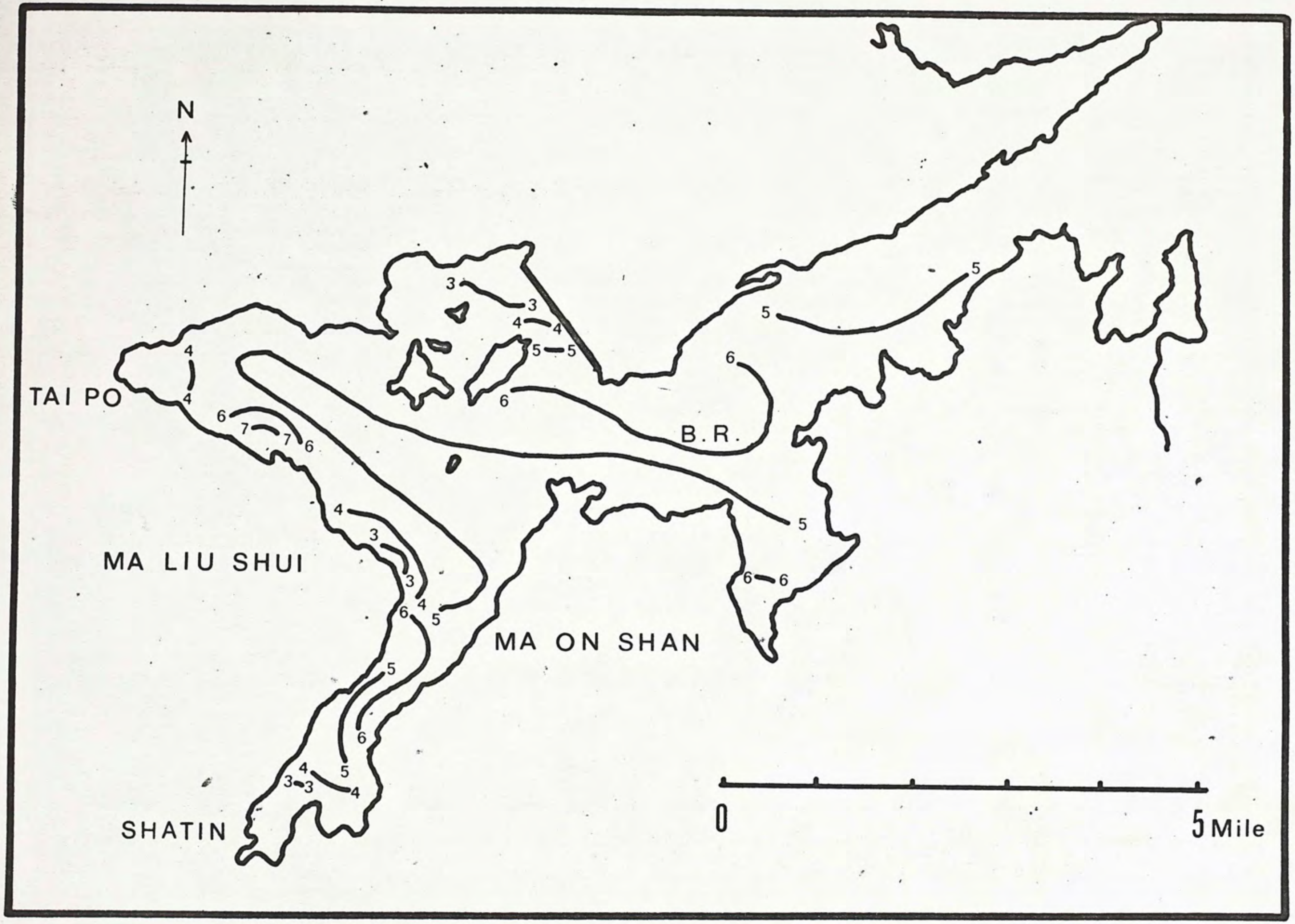


Figure 21 : Distribution of surface water BOD_5 in Tolo Harbour (on 13th May, 1971) (in ppm)

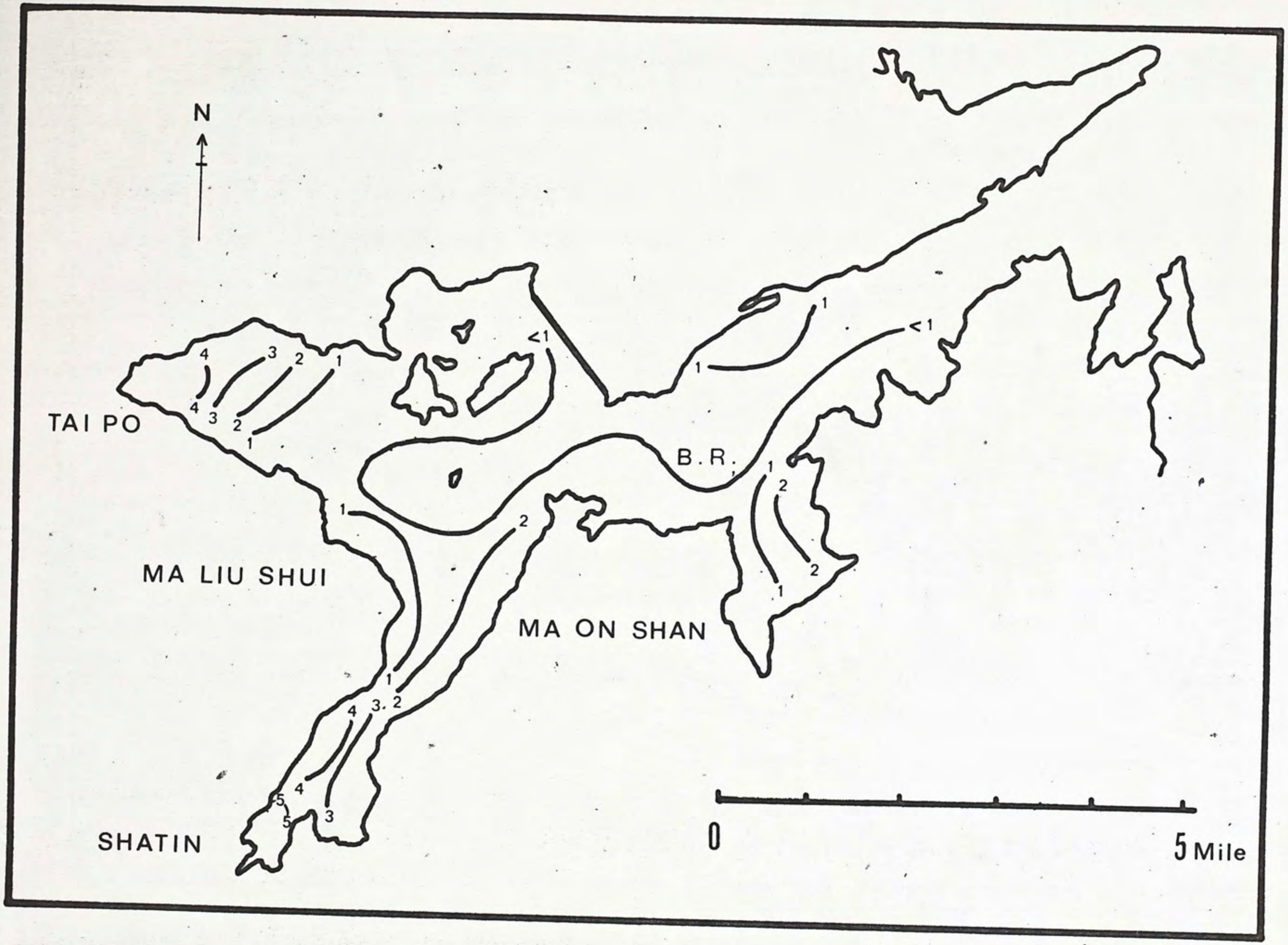
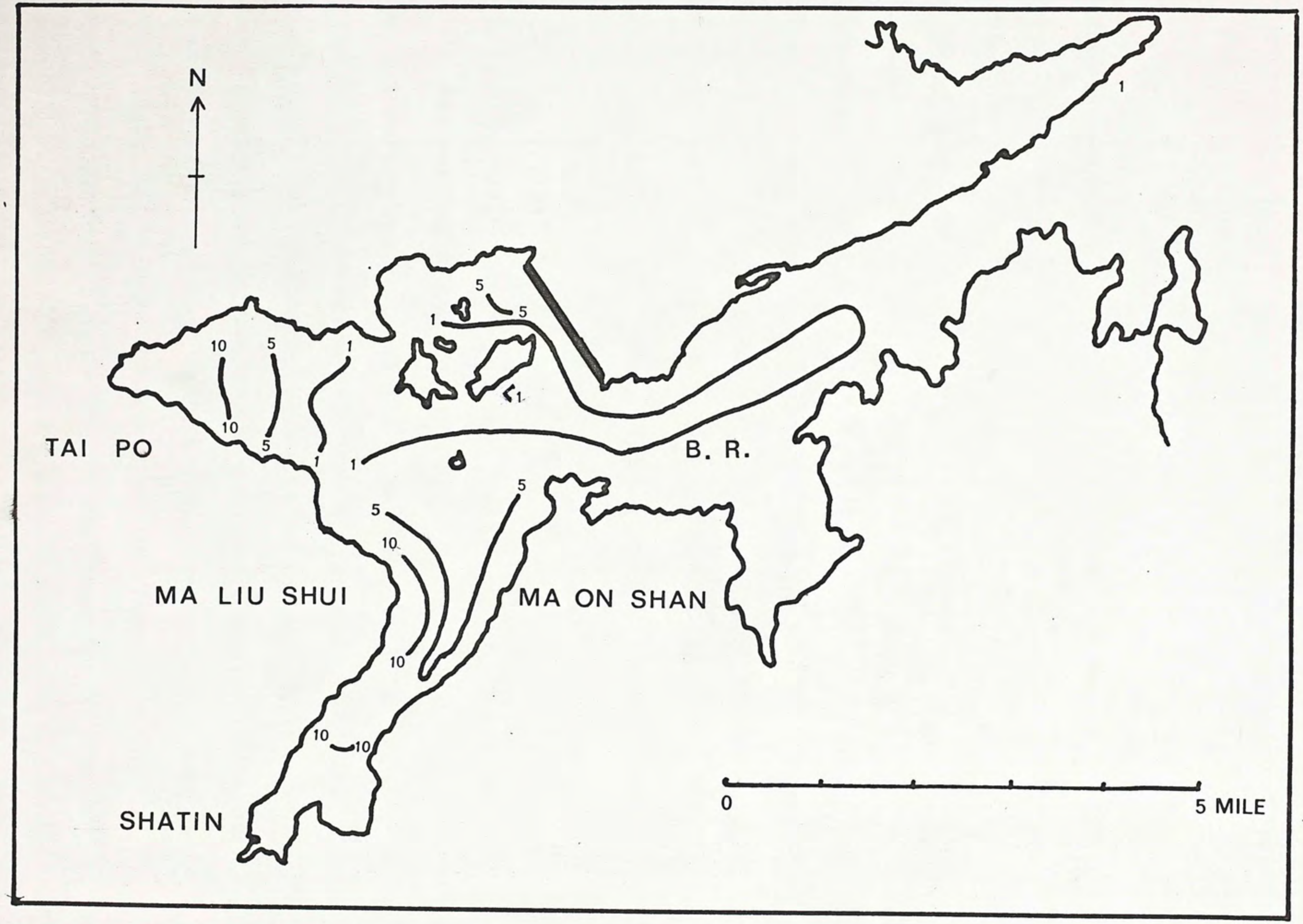


Figure 22 : Distribution of coliform bacteria in the sediments of Tolo Harbour (on 6th March, 1971) (in 100 MPN/cm.^{2})



DISCUSSION

There are some common characteristics which are shared by all the stations and which have apparently climatic causes, and could have nothing to do with human interference.

1) The monthly variations of surface water temperatures at the various stations are mainly seasonal, with the maximum and minimum readings reported in July and January respectively. These can be compared with the corresponding monthly air temperature (Appendix I, data extracted from Hong Kong Annual Report for the year 1971 (Hong Kong Government Press, 1972), and daily weather reports for January 1972 and February 1972 (issued by the Hong Kong Royal Observatory)). It is found that July and January were also the hottest and coldest months respectively.

2) The salinity changes are also mainly seasonal and are a result of scanty or heavy rainfall, as could be seen from the total rainfall of Hong Kong in the corresponding months (Appendix I). Not only the rainfall that directly falls into the sea lowers the salinity, the rain falling upon the land is collected by the rivers, streams, and drainage works all of which finally drain into the sea and result in the dilution of the sea water. It should be borne in mind that Hong Kong is located at the mouth of the Pearl River. Therefore in addition to the local effect of surface runoff there is the influence of the West River (a tributary of the Pearl River), with its maximum discharge occuring during the wet season

June - August, affecting the water salinity of Hong Kong (Williamson, 1970).

3) The dissolved oxygen content is the least in the hot months and is the greatest in the cold months. The seasonal changes may be due to biological activities and physical causes (Sverdrup et al, 1942). The major cause for the seasonal fluctuation of dissolved oxygen concentration however is the rise and fall of temperature (Klots and Benson, 1963). For instance, January, 1972 was the coldest month; the dissolved oxygen content was the greatest (Figure 7). The saturated value given in Zubov (1957) was exceeded. Supersaturation was recorded.

After the climatic factors have been considered, it is possible to examine the remaining factors with a view to establishing their effect upon the overall pollution of Tolo Harbour. Significant hydrological differences were found between the various stations e.g. nutrient salt levels and numbers of coliform bacteria. These will be discussed one station after the other with respect to the different factors. Comparisons are made to the standards, average values, and findings of other workers upon local waters and waters in other parts of the world. To facilitate these comparisons Table XVIII has been prepared. Most of the material included in this table has been reported earlier in the thesis.

Table XVIII : A summary of normal average values, international standards, results of work on local problems and problems in other places of the world.

	Normal average or International standards	local	other places
Temperature	————	Annual mean: 22.5-24.0 ^{o}C. Min.: 16 ^{o}C. (Feb) Max.: 28 ^{o}C. (Jun.-Sep.) (Williamson, 1970)	————
Turbidity (Secchi disk)	————	————	Clear water : 25 feet (Waldichuk, 1959) 'Turbid' water : * 2 m. (Bartsch <u>et</u> <u>al</u>, 1967)
Salinity	35.3 ^{o}/oo at 20 degree lat. (Sverdrup <u>et</u> <u>al</u>, 1942)	29-34 ^{o}/oo (Williamson, 1970; Watts, 1971 b)	South China Sea 34.4-34.6 ^{o}/oo (NE monsoon) 33.0-34.0 ^{o}/oo (SW monsoon) (Watts, 1971 a)
pH	8.1-8.3 (Sverdrup <u>et</u> <u>al</u>, 1942)	————	————
Dissolved oxygen	<u>U.S.A.</u> (N.Carolina) # >4.0 ppm (World Health Organization, 1967) <u>Japan</u> # >5 ppm (Nitta, 1961)	✓ 4.6-5.2 ml./L. (January) (Watts, 1971 b)	5.5-13 mg./L. (Waldichuk, 1959) 4.17-9.89 ppm (Jeffries, 1962)

* 1 m. = 3.3 ft. app.
\# 1 ppm = 1 mg./L. app.
✓ 1 ml./L. = 1.4 mg./L. app. at NTP

Table XVIII : (continued)

Phosphate-phosphorus	1-60 µg./L. * (Harvey, 1966)	0-1.00 µg.a./L. (Watts, 1971 b)	0.03-1.00 µg.a./L. (McNulty et al, 1959) 1.78-4.29 µg.a./L. (Jeffries, 1962) 0.2-3.2 µg.a./L. (Becacos-Kontos and Dugdale, 1971)
Nitrate-nitrogen	1-600 µg./L. # (Harvey, 1966)	0-350 µg./L. # (Chau, 1962)	5.09-23.0 µg.a./L. (McNulty et al, 1959) 6.7-34.7 µg.a./L. (Jeffries, 1962) 0.2-2.5 µg.a./L. (Becacos-Kontos and Dugdale, 1971)
Coliforms (water)	New Zealand (Shellfish) < 50/100 ml. (Bathing) <1000/100 ml. (World Health Organization, 1967) U.S.A. (Calif., W. of Virginia) (Bathing) < 1000/100 ml. (Garber, 1956)	Nil-118,000 (Jan.1970-May 1971) (H.K.Govt. Inform. Service)	1.1-290,000 MPN/100 ml. (McNulty et al, 1959)
(sediment)	———	———	Nil-92,000 MPN/cm^2 (Rittenberg et al, 1958)
Biochemical oxygen demand (BOD_5)	U.K. 20 ppm ♥ Czechoslovakia 5 mg./L. U.S.S.R. 2 mg./L. (World Health Organization, 1967)	———	———

* PO_4-P : 1 µg./L. = 0.0105 µg.a./L. app.
# NO_3^--N : 1 µg./L. = 0.016 µg.a./L. app.
♥ 1 ppm = 1 mg./L. app.

(1) Bush Reef :

Bush Reef is located in the centre of the harbour. It is more remote from the populated areas. The annual mean temperature (Table XIV) is within the range of the annual mean temperature of the waters around Hong Kong (Table XVIII).

With a vertical turbidity reading of approximately 20 feet, the water is fairly clear using the standard of Waldichuk (1959). The water is reasonably clean, so that the vertical turbidity is low; usually two or three times lower than the other stations.

With reference to the values of salinity given in Table XVIII, it can be seen that Tolo Harbour is an estuary condition with a lower salinity than that of the open ocean. However, more saline water is always found at Bush Reef (Table III and XVIII). The higher salinity of the water at Bush Reef is a closer approach to that of the normal sea water around Hong Kong. Consequently, Bush Reef should be cleaner than the other stations because a higher salinity is always associated with the cleaner spots of a bay (Crippen and Reish, 1969). In these localities it is least affected by sewage and dirty stream water.

With the exception of June and January, the pH of the water at Bush Reef is within the normal pH of 8.1-8.3. There are exceptional cases, but these cases are fewer in number when compared with the other stations.

Comparing the findings of Watts (1971 b) and Chau (1962), the inorganic nutrient levels at Bush Reef are not high. These values are the least of all the five stations (Table XV). High concentrations of chemical nutrients such as phosphate-P have always been related to high pollution (McNulty et al, 1959) and conversely that the locality with the least concentration may be regarded as less polluted.

Bush Reef is the least polluted area as is shown in the coliform MPNs. The MPN method has a very large sampling error. It has been demonstrated that when five tubes are used for each of the tenfold dilutions, the MPN given by the tables may be too high by 260 % or too low by 70 % of the real value (Halvorson and Ziegler, 1933). Many standards have been set according to the MPN values, but to consider the degree of pollution the logarithm of MPN is used (McNulty, 1961), because the exact figure would be no more meaningful than would be the order of magnitude. At Bush Reef the absolute values for the coliform counts vary greatly, but the order of magnitude is consistently around 10^1. The annual mean is the lowest of all the five stations.

In many places of the world, standards have been established for the highest permissible limits of coliform bacteria, depending upon the uses to which the water is put (Table XVIII). In Hong Kong, no official standard has been set. However, many beaches of Hong Kong are polluted if the standard of 1,000 MPN/100 ml. is adopted. For instance, South Bay on May 5, 1971, was reported of 118,000 MPN/100 ml. (H.K. Government Information Service), which is more than one hundred times the accepted value. Compared with the standards set for bathing beaches and for the collection of edible clams, the water at Bush Reef is clean and is suitable for bathing and other purposes. The coliform bacterial counts remained at a low level all the year round and the levels were not very different in February 1972 from those levels reported upon at the beginning of the study (Table IX).

For the sediments, the annual mean is the lowest of the five stations. There are no existing standards for the coliform bacteria population found on the sea bottom or in the sediments. Rittenberg et al (1958) investigated the coliform bacteria in sediments around three marine sewage outfalls and attributed the population of coliform bacteria, which are concentrated first in the surface layers of the water and then settle to the bottom, to the sewage effluents. The low coliform counts in the bottom sediments at Bush Reef show that this region of the barbour is not influenced to any great extent by human activities.

The dissolved oxygen content at Bush Reef is satisfactory and is the highest among the five stations. The annual mean is greater than the standards in the U.S.A. (North Carolina) or Japan. At Bush Reef, the BOD_5 is the lowest of the five stations all the year round, which confirms that Bush Reef is least affected by organic wastes (Table XIII). The average for the year (Table XVII) is below the standards set by any country (Table XVIII).

Since the conditions found at Bush Reef approximate to the conditions found in a body of non-polluted water, the hydrological characteristics of Bush Reef can be used as points of reference when we examine the other stations in the harbour.

(2) Shatin :

Shatin is probably the most polluted area of the five. The 1971 Census gives a figure of 29,478 people living in Shatin. Unofficial estimates, however, put the figure at 80,000 apparently including those people living in surrounding villages. There are plans for the establishment of a race horce track on the newly reclaimed land, the building of new roads and the reconstruction of the whole town. These plans are aimed at developing Shatin into a satellite town with an expected population of half a million people in order to ease the dense, overcrowded conditions in Kowloon. However, present conditions at Shatin are by no means satisfactory. The effects of the improperly treated sewage and careless disposal of refuse are visible even to a layman. The seashore is littered with used cans, broken glass bottles, plastic bags and other forms of garbage. The water is dirty, light penetration being less than 6 feet (Table II and Figure 3). Moreover, the sea is usually colored by the dyes carried from the waste effluents of the Jardine Dyeing Factory located only a mile from the town. Shatin is a popular picnic spot during the holidays. The picnickers do not take care of the environment, leaving their rubbish everywhere. On many occasions, human faeces have been observed floating on the sea water, seemingly disposed of by the people that live in huts or houses along the streams leading to the sea.

Though the surface water temperature in general is more or less the same as the other stations (Figure 2), water samples that are taken within a hundred yards of the outlet from the dyeing factory normally are more than $10^{\circ}C.$ higher than the normal water temperature (K.F. Ho, 1972, unpublished results). The thermal pollution effect, however, is diluted further seawards from the factory.

The water at Shatin is often less saline than that at other stations (Figure 4 and Table XIV). The annual mean is more than a part per thousand less than the salinity of water at the other stations. This lower salinity can be attributed to the location of the Shatin Hoi, being at the innermost portion of Tolo Harbour. The circulation of the water in the harbour affected as it is by tidal flushing and the inflow of streams and sewers has a very complex pattern. It was observed during our regular visits that the flow is sluggish at the surface. This observation was supported by the salinity results. The capacity for absorbing, mixing, and removing foreign fresh water is low thus resulting in the low salinity readings.

The unsatisfactory water quality is also indicated by the relatively lower dissolved oxygen content, with an annual mean that is the lowest of the five stations (Table XIV). However, measured by the standards of the U.S.A. (North Carolina) and Japan, it is still a little above the limit. On the other hand, the annual mean of BOD_5 is the highest of the five stations (Table XVII) and is greater than the standards imposed by the U.S.S.R. All of these recordings are consistent with the dissolved oxygen and BOD_5 gradients observed on May 13, 1971 (Figure 20 and 21). The conditions of low dissolved oxygen and high biochemical oxygen demand rendered many parts of the Shatin mudflat anaerobic and the mud smelt strongly of hydrogen sulphide (Trott, 1972 c, In press). This may also account for the greater range and lower pH of the water (Figure 5). In many cases the pH at Shatin was not within the normal range.

That the water is greatly affected by sewage outfall is reflected by the high concentrations of phosphate and nitrate. These of course are not high compared with the values given for 'average' sea water by Collier (1970), nor with the findings of McNulty et al (1959) and Jeffries (1962). Compared with the water at Bush Reef, and the normal concentration of nitrates and phosphates in the waters around Hong Kong (Chau, 1962; Watts, 1971 b), the phosphate and nitrate levels at Shatin are very high.

The coliform bacterial counts at Shatin are alarming. In the surface water, there is a consistently high density of coliform bacteria i.e.$>10^3$ (Table IX), exceeding the highest permissible standard for bathing and edible mollusc collection (World Health Organization, 1967). The annual mean calculated from actual MPNs is higher than the annual mean calculated from log MPNs (Table XVI). The mean calculated from individual log MPN is more reliable because the deviation is not unnecessarily magnified (Appendix II). There are fluctuations in the number of coliform bacteria but the overall trend is one of increasing numbers (Figure 10). The coliform counts in February, 1972 were 70 times the values obtained in March, 1971 when the study began (Table IX).

The high concentration of coliform bacterial counts in the water is evidenced by the similarly high coliform counts in the sediments (Table XI).

The sources of pollution are the sewage outlets, rivers, and streams which carry domestic sewage into the sea. High concentrations of coliform bacteria were recorded in the Shing Mun River (Figure 12). There were more coliform bacterial counts on the western side of Shatin Hoi because this part is near to the part of Shatin which is most populated (Figure 13 and 14). The highest MPN count (64,000) is comparable in the order of magnitude to the highest reading of 92,000 that Rittenberg et al, (1958) obtained at White's Point. Because of the bactericidal effects (Ketchum et al, 1952), the coliform bacteria concentrations decrease farther away from the sewage outfalls (Figure 22).

The high coliform bacterial counts reflect a state of heavy pollution. My preliminary tests on the 3 species of clams had already demonstrated this. Y.K. Ho worked on the pollution of edible mollusks at Shatin as his senior seminar project. His unpublished results were tabulated in Appendix III. Out of 66 tests, only 8 tests showed 80-100 % clean. This indicates the unhealthy condition of Shatin. The shellfish are contaminated. It is dangerous to eat the clams collected there.

(3) Tai Po :

The condition of the water of Tai Po is not better than the water at Shatin (Table XIV - XVII). Tai Po has always been known as a fishing village and is inhabited by several thousand people who make their homes on boats. In addition, forty thousand people live in the town. The people on the fishing junks and on the 'squatter' boats have no other way of disposing of their waste and refuse but to dump them directly into the sea. Therefore, on the water, plastic bags, fruit peels and faeces are not an uncommon sight. These and the sewage from the town proper make the water very turbid.

The effect of dirty fresh water is shown by the lowering of salinity, lowering of dissolved oxygen, and a greater range of pH (an extreme of 9.30 was recorded in June, 1971), when we compare these parameters with those recorded at Bush Reef (Table XIV).

The influence of the sewage is also apparent in the high phosphate and nitrate contents (Table XV). In the early summer, when the water is warm enough, vast quantity of green algae can be seen on the surface of the water, the predominant genus being Ulva. The local people collect them, dry them up and use them as medicine.

The degree of pollution is well illustrated by the high coliform bacterial counts both in the water and in the sediments and the high BOD_5 of surface water (Table XVI and Table XVII). All of these figures, especially the coliform bacterial counts, are comparable to the findings at Shatin. The sewage from the town was the source of pollution. There were high concentrations of coliform bacteria in the part of sea near the shore and the coliform bacterial counts decreased farther from the land (Figure 15 and 16). The comparison of the stations in a polluted bay described by Jeffries (1962) can be applied here. For coliform counts, arranged in increasing order, Bush Reef < Shatin = Tai Po. A similar relationship is found with respect to BOD_5 and the inorganic nutrients. It is interesting to note that the coliform bacterial counts in the water of Tai Po found in February, 1972 were 12 times greater than those found at the beginning of the year. The rate of the deterioration of the water at Tai Po is great, but is lower than that at Shatin.

(4) Ma Liu Shui :

This is a moderately polluted area. The effect of domestic pollutants are apparent when the hydrological data are compared with those of Bush Reef. That this place is less polluted is due to the fact that, compared with Shatin and Tai Po, it is less populated and is nearer to the centre of the harbour where circulation is faster.

The number of coliform bacteria in the water is consistently below 10^2. This means that it is still safe to swim at Ma Liu Shui, as many people do in summer, since the highest permissible limit is still not exceeded. However, the deterioration of the water, as measured by the coliform bacterial counts at the beginning and at the end of the year studied, is proceeding at a rate of approximately 5 times per year. If nothing is done, Ma Liu Shui may eventually have to be closed to bathers.

At Ma Liu Shui, on the campus of the Chinese University of Hong Kong, a sewage treatment plant was built and has been in small scale operation since November, 1971. The sewage treatment plant consists of a series of settling tanks, a sludge digester, an aeration tank and a chlorination tank. It is hoped that the University will not be a source of pollution.

(5) Ma On Shan :

A comparison of the hydrological results, phosphate and nitrate levels, coliform bacteria counts and biochemical oxygen demand of the water at Ma On Shan with those at Ma Liu Shui shows nearly identical conditions (Table XIV - XVII). This is because these stations are only a mile apart. However, this proves that 'the effect of the Ma On Shan iron mine is promarily of sedimentation interest, and is of apparently little impact to the ecology of the Harbour' (Trott, 1972 c, In press). This explains also why the water at Ma On Shan is more turbid at most times than the water at Ma Liu Shui.

The comparison now can include two more stations. Arranged in increasing order the coliform bacterial counts show the following relationship, Bush Reef $<$ Ma Liu Shui = Ma On Shan $<$ Shatin = Tai Po. The same relationship is true also for BOD_5 and the concentrations of phosphate and nitrate.

SUMMARY AND CONCLUSIONS

(1) Pollution is a necessary evil resulting from over-population. Hong Kong, with its rapid increase of population, enjoying on one hand its rapidly developing economy and prosperity, will have to pay the cost of the pollution of the water on the other.

Without human beings and their activities there would not be any pollution of the environment. In Tolo Harbour, the human influence comes mainly from human and domestic sewage. The influence of industrial activity is slight becuase there are only two major industrial concerns of any importance, the Ma On Shan iron mine and the Shatin dyeing factory. Their effects are localised affecting little the ecology of the harbour as a whole.

(2) This one year survey reveals that the five stations visited show three stages of pollution. First, it is at Bush Reef which is remote from densely populated lands and least affected by human waste and domestic sewage. This is evidenced by the relatively normal salinity and pH, high dissolved oxygen content and low BOD_5. The water is clear and the inorganic nutrients are not excessively high. Bush Reef is still polluted or is beginning to be polluted because coliform bacteria, which normally cannot survive in marine environment, are continually detected both in the water and in the sediments. The degree of pollution is slight and bathing is safe at present.

(3) Secondly, there are the stations at Ma Liu Shui and Ma On Shan. Both are inhabited by a few thousand people and both are located on the more sheltered parts of the harbour. The sewage from both these two towns is discharged into the sea with very little treatment; a sewage treatment plant built on the campus of the Chinese University of Hong Kong started small scale operation only recently in November, 1971. The polluted conditions are evidenced by more turbid waters, lower salinity, lower dissolved oxygen content and a greater range of pH. The inorganic nutrient levels and BOD_5 are relatively higher. The degree of pollution as shown by the coliform bacteria counts is still well below the minimum standards set for safe bathing but already exceeds the highest permissible limit for the collection of edible molluscs.

(4) Thirdly, there are the densely populated "satellite" towns of Shatin and Tai Po, one located on the south western end and the other on the north western end of Tolo Harbour. Both these towns are undergoing rapid development. Though complete knowledge on the circulation pattern of the water is still not at hand, it is observed that the current is very sluggish and that the normal removal of waste substances, relying as it does on natural tidal flows, is no longer effective. Moreover, without careful planning and proper supervision over the treatment and disposal of waste products, these areas have already been polluted. At the present time, as shown by the coliform bacterial counts, concentrations of inorganic nutrients and other

hydrological factors such as salinity, pH, turbidity, dissolved oxygen and BOD_5, the degree of pollution is very high. Bathing may become dangerous in the future and the molluscs collected in these areas are no longer safe for consumption. It has been demonstrated that a high percentage of the clams collected from Shatin mudflat are contaminated.

(5) Pollution can be prevented and its detrimental effects can be eliminated, if a sound knowledge of its causes and existing conditions are at hand. It is to this end that this study is aimed. Pollution can be a disaster but it can be turned to profitable ends. All we need is foresight and some planning. It is a pleasure to note that the Advisory Committee on Environmental Pollution on Land and Water has been formed to take care of the environment of the Colony.

(6) This study of a local ecological problem is the first one of its kind in this part of the world. The results are useful not only in unveiling the polluted conditions of Tolo Harbour so that actions can be taken to prevent further pollution in this place and other areas of Hong Kong, but may also be used as background material in later research on the circulation, productivity, fauna and flora of the harbour.

(7) The investigation of pollution problems opens a wide field of research which could be attacked from all angles either physiologically, chemically, physiochemically or microbiologically. Since

this is a general ecological survey, no attempt has been made to assay the toxicity of the effluents from the industrial factories nor to detect any pathogenic microbial species from the sewage of the towns. It is hoped that other research workers will look into these aspects to provide more information on the pollution of the harbour.

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APPENDICES

Appendix I: The monthly mean air temperature and total rainfall in Hong Kong in 1971-72

	AIR TEMPERATURE (^{o}C)	RAINFALL (mm.)
Mar.	28.4	1.1
Apr.	23.1	17.9
May	25.9	172.7
Jun.	28.5	434.5
Jul.	28.8	324.4
Aug.	28.1	525.5
Sep.	27.9	194.5
Oct.	24.2	26.0
Nov.	20.8	Trace
Dec.	17.3	175.1
Jan.	14.8	46.5
Feb.	15.3	22.0

Appendix II: A worked example on MPN and log MPN

The MPN method for the detection and determination of coliform bacteria depends upon probability has a great sampling error and has defects in its expression. A defect is the magnified deviation of two results which really show a similar condition. This defect can be lessened using the logarithm of MPN instead of the actual MPN as an expression of the results, as described by the following worked example. For instance, with a highly polluted water sample, inoculation using 5 tubes each of 10 ml., 1 ml. and 0.1 ml. may give a result of 5, 5, 3 positive tests for the 3 volumes. The MPN as given in the Check Table of Standard Methods is 920. Inoculations of a similar sample at the same dilutions may give a result of 5, 5, 4 i.e. the 0.1 ml. tube shows an additional positive result. This will give a MPN of 1600. In other words, a slight difference in the result obtained from one tube gives a MPN with a difference of 680 or 42%, which can easily be interpreted as an inconsistent result. However, if expressed as logarithmic numbers, the former will be 3.20 and the latter 2.96. In this manner the results are shown to be of the same order of magnitude and the difference is only of the order of 8%.

Appendix III: Results of Y. K. Ho's study on bivalve molluscs from Shatin mudflat tested for coliform bacteria.

Genus	Total no. of tests	No. of tests 0-60% clean	No. of tests 70% clean	No. of tests 80-100% clean
Tapes	21	18	1	2
Katelysia	15	12	1	2
Mytilus	4	4	0	0
Anadara	3	3	0	0
Ostrea	7	4	0	3
Pinctada	6	5	1	0
Anomalocardia	10	8	1	1
TOTAL	66	54	4	8

N. B. According to Collins (1967), the 'Percentage Clean' method for shellfish is to take 10 shellfish and test for the presence of Coliform bacteria. If coliform bacteria are absent from all 10 shellfish they are '100% clean'. If they are absent from eight out of 10 they are '80% clean' and so on.

If is regarded that '80-100% clean' as satisfactory, '70% clean' as suspicious and '60% clean' or less as unsatisfactory.